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CLASSIFICATION OF THIS PAGE

(2)

REPORT DOCUMENTATION PAGE			
AD-A196 450		DTIC FILE COPY	
LECTER JN 30 1988 D		1. RESTRICTIVE MARKINGS	
DUE		3. DISTRIBUTION/AVAILABILITY OF REPORT	
		Approved for public release; distribution unlimited.	
4. PERFORMING ORGANIZATION REPORT NUMBER		5. MONITORING ORGANIZATION REPORT NUMBER(S)	
University of Minnesota		AFOSR-TK- 88-0684	
6a. NAME OF PERFORMING ORGANIZATION		6b. OFFICE SYMBOL (If applicable)	
University of Minnesota		AFOSR/NL	
6c. ADDRESS (City, State and ZIP Code)		7b. ADDRESS (City, State and ZIP Code)	
1919 University Avenue St. Paul, MN 55104		Bldg. 410 Bolling AFB, DC 20332-6448	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION		8b. OFFICE SYMBOL (If applicable)	
AFOSR/NL		NL	
8c. ADDRESS (City, State and ZIP Code)		9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER	
Building 410 Bolling AFB, DC 20332-6448		AFOSR-87-0234	
11. TITLE (Include Security Classification)		10. SOURCE OF FUNDING NOS.	
Ability/ Motivation Interactions in Complex Skill		PROGRAM ELEMENT NO.	PROJECT NO.
		61102F	2313
		TASK NO.	A7
		WORK UNIT NO.	
12a. TYPE OF REPORT		13a. TIME COVERED	
Final Report		FROM 5/1/87 TO 2/29/88	
14. DATE OF REPORT (Yr., Mo., Day)		15. PAGE COUNT	
1988 April 28		67	
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB. GR.	Ability Motivation Learning Individual Differences Goal-Setting Skill Acquisition Self-Regulation
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
We propose and experimentally investigate a unified theoretical approach for understanding the simultaneous effects of individual differences in abilities and motivational processes in complex skill acquisition. The construct of "attentional resources" is used to provide a theoretical linkage between ability and motivation and to clarify the influence of objective task characteristics on the ability/motivation - performance relations. Specifically, abilities interact with motivational interventions (i.e., goal setting) and cognitive demands imposed by the task at different stages of skill acquisition. Two series of experiments, conducted at the Air Force Human Resources Laboratory, are reported that provide evidence for this framework.			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT		21. ABSTRACT SECURITY CLASSIFICATION	
UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS <input type="checkbox"/>			
22a. NAME OF RESPONSIBLE INDIVIDUAL		22b. TELEPHONE NUMBER (Include Area Code)	22c. OFFICE SYMBOL
Dr. John Tangney		(202) 767-5021	NL

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Subjects in each experiment engaged in complex, computerized Air Traffic Controller tasks. The two experiments in the first series assess the basic learning and ability/performance parameters of the task and examine the interactive effects of abilities and motivation during early and intermediate phases of skill acquisition. Results obtained in these experiments indicate the basic skill acquisition parameters of the Air Traffic Controller task. Consistent with the proposed model, the influence of general ability on performance attenuated as attentional demands of the task declined with practice. As predicted, goal assignments made during the intermediate stage of skill acquisition exerted a beneficial effect on performance for both high and low ability subjects. In the second series, an experiment was conducted to examine the simultaneous effects of task training content, goal setting, and ability/performance interactions. Evidence obtained provides support for theoretically-derived predictions of interactions among abilities, motivational mechanisms, and information processing demands of task performance. Implications for further investigation of ability - based individual differences in motivational processes and applications for the design of training programs are discussed.

AFOSR-TK. 88-0684

Ability/Motivation Interactions in Complex Skill Acquisition

FINAL REPORT
(Period 5/1/87 - 2/29/88)

**Ruth Kanfer
Phillip L. Ackerman**

**Department of Psychology
University of Minnesota
Minneapolis, MN 55455**

Submitted to

**Dr. John F. Tangney
AFOSR/NL
Washington, DC 20332-6448**

This is a Final Report prepared for the Air Force Office of Scientific Research.

88 6 29 118

SUMMARY

Two central constructs of applied psychology, those of motivation and cognitive ability, are integrated within an information processing perspective. We begin with a conceptual framework for simultaneous consideration of individual differences in cognitive abilities and volitional/self-regulatory processes of motivation. From this framework, we propose that motivational interventions (i.e., goal setting) specifically interact with abilities and task demands. Empirical demonstration of the framework is provided in the context of skill acquisition, where the information processing and ability demands change as a function of practice, training paradigm, and the timing of goal setting. Three skill acquisition/goal setting experiments are reported, in a large scale field-based lab setting (1,010 U.S. Air Force trainees). Subjects engaged in complex, computerized, Air Traffic Controller tasks. In the first experiment, the basic learning and ability/performance parameters of the task were evaluated in conjunction with a goal-setting intervention early in practice. Results offered support for the initial tenets of the framework, and point to a number of critical issues in the appropriate use of goal-setting in a complex learning environment. In Experiment 2, goal setting was further investigated at a later stage of skill acquisition, for demonstration of the interactions between task demands and motivational interventions. The third experiment simultaneously examined the effects of task training content, goal setting, and ability/performance interactions during skill acquisition. Results from this series of experiments support the theoretical framework for interactions among abilities, motivational mechanisms, and information processing demands of task performance. The integrative/aptitude-treatment interaction framework leads to a reconsideration of the basic notions of ability-motivation interactions, and to implications for design of training programs and motivational interventions. *Kernan, 1982*

Curriculum, 1982



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DTIC TAB	<input type="checkbox"/>
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PREFACE

This research was sponsored by the Air Force Office of Scientific Research and Project LAMP, under the auspices of the Air Force Human Resources Laboratory (contract AFOSR-87-0234), with matching funds from the University of Minnesota Graduate School and College of Liberal Arts, to R. Kanfer and P. L. Ackerman. This research investigated the effects of individual differences in abilities, motivational processes, and task demands during skill acquisition using a theoretical framework that permits examination of the simultaneous effects of these factors on performance. The authors would like to gratefully acknowledge Kim Pearson for his programming assistance, the cooperation of the Project LAMP in supervising the collection of the data reported here, including Dr. William Tirre, Dr. Dan Woltz, and especially the efforts of Dr. Valerie Shute.

Table of Contents

<u>Section</u>	<u>Page</u>
I. INTRODUCTION	1
II. GENERAL BACKGROUND	1
Attention as a Core Construct	2
Attention and Skill Acquisition	3
Attention and General Intelligence	5
Intelligence & Learning	5
Intelligence and Information Processing after Learning	6
Motivation and Attention	7
Distal Determinants of Effort Allocations	8
Proximal Determinants of Attention	10
Motivational Processes and Learning	11
Motivation and Performance	13
Summary of the Foundation	14
III. A MODEL OF ABILITY/MOTIVATION INTERACTIONS	14
Implications of the Ability/Motivation Model	15
IV. OVERVIEW: EXPERIMENTS COMPLETED UNDER THE GRANT	16
Description of the Task Paradigm	16
Feedback/Knowledge of Results	17
Task Rules	18
The Task Requirements	19
V. SERIES I - EXPERIMENT 1	19
Apparatus	19
Subjects	19
Procedure	20
Results	22
Discussion	26
VI. SERIES 1 -- EXPERIMENT 2	26
Subjects	27
Procedure	27
Results	27
Discussion	29
VII. SERIES II - EXPERIMENT 3	30
Subjects	31
Procedure	32
Results	33
Discussion	39
VIII. GENERAL DISCUSSION	39
Ability - Motivation Interactions	39
Ability Considerations	40
Motivational Considerations	40
Summary	42
IX. REFERENCES	43

List of Tables

Table		
Table 1.	ANOVA _s : Experiment 1	48
Table 2.	ANOVA _s : Experiment 2	49
Table 3.	Repeated-Measure ANOVA on Landings	50
Table 4.	Repeated-Measure ANOVA on Errors	51
Table 5.	ANOVA _s : Experiment 3	52

List of Figures

Figure		
Figure 1.	An example performance-resource function	53
Figure 2.	Changes in performance-resource functions as a result of practice	54
Figure 3.	A model of ability/motivation interactions for attentional effort	55
Figure 4.	The Kanfer/Ackerman Air Traffic Controller Task	56
Figure 5.	A list of operational rules for the ATC task	57
Figure 6.	An illustration of error feedback in the ATC task	58
Figure 7.	Ability/performance correlations by ability factor, condition, and ATC task trial	59
Figure 8.	Planes landed as a function of ATC task trial	60
Figure 9.	Ability/performance correlations	61
Figure 10.	Planes landed as a function of ATC task trial	62
Figure 11.	An illustration of a Declarative knowledge part-task training trial	63
Figure 12.	An illustration of a Procedural knowledge part-task training trial	64
Figure 13.	Ability/performance correlations	65
Figure 14.	Planes landed as a function of full ATC task trial	66
Figure 15.	Planes landed -- Trial 6	67

ABILITY/MOTIVATION INTERACTIONS IN COMPLEX SKILL ACQUISITION

I. INTRODUCTION

A persistent, but unresolved problem in the assessment of individual differences in learning abilities concerns how motivational processes and cognitive effort jointly affect individual differences in knowledge and skill acquisition. To date, normative studies of learning in the information-processing domain have focused largely on the cognitive structures, components, and processes involved during skill acquisition. In such studies, the effects of specific motivational factors and individual differences have been generally ignored. Of course, numerous researchers have indicated that motivation likely influences the extent to which persons sustain interest and effort toward task acquisition. Studies examining the effects of individual differences in abilities during skill acquisition have similarly neglected the potential influence of motivation as a moderator of ability determinants of performance.

Historically, researchers have attempted to enhance task interest and effort by providing persons with a general incentive, such as financial payment contingent on performance, to ensure sufficient task motivation. In other cases, performance goals and feedback have been provided to enhance motivation, and thus learning. Although these factors may sustain task interest, it has not been clear how motivational processes triggered by these procedures affect the cognitive processing involved in knowledge and skill acquisition.

The purpose of the research is to investigate the joint effects of motivational processes and cognitive ability determinants of individual differences as they pertain to skill acquisition and sustained task performance. While the research is grounded in general theory of information processing and skill acquisition, two disciplines of research and theory are employed to provide a unified approach to the motivational and cognitive determinants of complex skill learning. Specifically, this program of research is based on (a) a theory of the cognitive determinants of individual differences in skill acquisition (Ackerman, 1986a, 1986b, in press(a), in press(b)), and (b) a theory of the motivational determinants of learning and performance (Kanfer, 1986, 1987, in press, Kanfer & Paullin, 1986). The unified framework details how task demands, motivation, and critical cognitive abilities interact in determining individual differences in initial performance, rate of learning, and asymptotic skilled performance on complex tasks. The research examines the joint influence of abilities and motivation on skill acquisition and asymptotic performance. The research program will empirically validate the unified framework of cognitive, motivational, and information processing determinants of individual differences in learning. The paradigmatic investigation of these factors will ultimately provide a rubric for increasing the precision of measures to assess individual differences in learning abilities.

II. GENERAL BACKGROUND

The first step in establishing a theoretical foundation for our approach to ability/motivation interactions is to define some terms and provide some historical/theoretical justification for the linkage between constructs from the intelligence and motivation domains. The fundamental basis for fitting these constructs together is the concept of cognitive/attentional resources. From this foundation, abilities are represented in terms of individual differences in resource capacity (or resource efficiency). Information processing constraints are considered in terms of resource demands on the learner over the course of skill development (which change as

a result of the development of task-specific procedural knowledge). Finally, motivational processes are studied in terms of changes in resource allocation policies, as well as changes in resource availability that occur during self-regulatory (metacognitive) processes.

Attention as a Core Construct

For an integrative discussion of intellectual abilities/motivation interactions during skill acquisition, it is necessary to have a common metric as a theoretical foundation for each individual area. The construct of "cognitive-resources" or "attentional-resources" provides such a common metric. A short discussion of attentional resources is given below.

The Performance-Resource Function. The performance-resource function postulated by Norman and Bobrow (1975) provides a language for understanding the relation between cognitive effort/attention and level of performance, under a variety of information-processing task constraints. Norman and Bobrow proposed two ends of a continuum that describe effort-performance relations. The two concepts are: (1) performance limitations based on the amount of cognitive or attentional resources devoted to a task; and (2) performance limitations imposed by task characteristics. These concepts have been respectively termed "resource-limitations" and "data-limitations." The performance-resource function describes the functional relationship between the amount of cognitive/attentional resources devoted to a task and the resulting level of performance on that task. The only explicit assumption about such functions is that they are monotonically increasing. That is, it is assumed that performance will not decrease when additional resources are devoted to the task. One should note, then, that factors such as "over-arousal" that impair task performance would imply a reduction in the amount of resources given to a task (consistent with current theories of stressor effects -- see Hancock, 1984).

With this framework, a task is said to be "resource-limited" when increases or decreases in the amount of attention devoted to the task result in marked changes in objective task performance. Conversely, a task is said to be "data-limited" when changes in amount of attention do *not* result in substantial changes in performance. Basically, information processing demands can be classified to indicate performance-resource functions that show tasks to be *dependent* or *insensitive* to changes in attentional effort devoted to the task.

As depicted in Figure 1, a task is resource-dependent whenever an increase (or decrease) in the amount of attention devoted to a task is accompanied by a change in level of performance. Conversely, when performance is limited, not by allocation of attention, but by the nature of the task, the task is resource-insensitive. That is, changes in the allocation of attention result in minimal change to performance level. In the hypothetical task depicted in Figure 1, there are two areas of resource-insensitivity. At low levels of attention, there is essentially a threshold for any performance marginally above zero. At the upper range of attention, there is a situation of diminishing returns. That is, an increase from 90 to 100 percent attention results in a minimal change in performance level. Note that the task is considered to be resource-dependent when the slope of this performance-resource function is steep.

Insert Figure 1 about here

It turns out that the function relating performance and resources is altered under several key situations. When the difficulty of a task changes, say, by increasing the load on memory, the performance-resource function may become increasingly attentional resource-dependent. Conversely, when the task is simplified, the slope of the performance-resource function decreases (the task becomes resource-insensitive). Similarly, under conditions of skill acquisition, a task that is initially resource-dependent will ordinarily become progressively more resource-insensitive with task practice. As Figure 2 shows, with additional practice, higher levels of performance are possible, along with decreasing demands on attention (Ackerman, 1987; Norman & Bobrow, 1975). The nature of these performance-resource function changes over task practice is the source of the discussion below.

Insert Figure 2 about here

Attention and Skill Acquisition

Several skill acquisition theorists have found it parsimonious to incorporate stage or phase designations to delineate different aspects of the learning process. Anderson (1982, 1983), for example, has suggested that from a production system perspective, skill acquisition can be segmented into three phases: "Declarative Knowledge" (Phase 1), followed by "Knowledge Compilation" (Phase 2), and finally, "Procedural Knowledge" (Phase 3). Such division of the skill acquisition process into three phases has a long history (see Fitts, 1964 for an example, see also a review by Adams, 1987), but most theorists ultimately consider skill acquisition to be a continuous, rather than a discrete process (Adams, 1987; Newell & Rosenbloom, 1981). For the present concerns, the distinction between the first and last phases is of critical importance, though all three Phases will be described for the sake of completeness.

Phase 1 -Declarative Knowledge. Declarative knowledge is defined as "knowledge about facts and things" (Anderson, 1985, p. 199). The *declarative knowledge* phase of skill acquisition appears to involve all of the requisite memory and reasoning processes that allow the learner to attain an "understanding" of the task requirements. The content of a task at this point often consists of the specification of task objectives (i.e., some end result of proficiency or task completion) and frequently includes instruction about the task, as would be exemplified by a lecture on a mechanical system or general principles for equipment operation. During this phase the learner may examine the objectives of the training program, may observe demonstrations of the task, may encode and store task rules, and may derive strategies for approaching the task.

One critical aspect of the declarative phase of skill acquisition is the extent of attentional resource demands made on the learner. When learners perform at this level of skill acquisition, they devote most, if not all of their attention to understanding and performing the task in question. When confronted with additional information processing requirements, as with the inclusion of a secondary task, learners are unable to adequately devote attention to the secondary task *and* to the learning of the criterion task simultaneously (Nissen & Bullemer, 1987). In this sense, there is an equivalence between demands on the declarative knowledge system and demands for attentional resources.

Finally, in the declarative knowledge phase, performance is slow and error prone. Once the learner has come to an adequate cognitive representation of the task, he or

she can proceed to the second stage, that is, the *knowledge compilation* phase.

Phase 2 - Knowledge Compilation. For *consistent* tasks¹, performance speed and accuracy markedly improve over the course of practice. During the *knowledge compilation* phase of skill acquisition, learners integrate the sequences of cognitive and motor processes required to perform the task. As various methods for simplifying or streamlining the task are tried and evaluated, performance generally becomes faster and less error-prone than in the declarative knowledge phase. Anderson (1985) indicates that the process of knowledge compilation is analogically similar to the process of compiling interpretive computer source code (the actual program statements) to obtain object code (or machine-level code). As this compilation occurs for each task component, the declarative knowledge system (i.e., the attentional apparatus) is relieved of the processes originally required to perform the task. As such, the attentional load on the learner is reduced as the task objectives and procedures are moved from short-term or working memory, to long-term memory (Fisk & Schneider, 1983).

When a competing task is added to the learning task during the knowledge compilation phase, performance on the learning task may not improve to the same degree as under single task conditions, but the learning task skill appears to be less susceptible to interference from external attentional demands (Yeh & Schneider, 1985). Therefore, attentional resources may be diverted from the task, or used for processing other components of the entire skill without resulting in the substantial decrements associated with removal of attention when the learner is at the declarative knowledge phase of skill acquisition.

Phase 3 - Procedural Knowledge. Procedural knowledge is defined as "knowledge about how to perform various cognitive activities" (Anderson, 1985; p. 199). This final phase of skill acquisition is reached when the learner has essentially automatized the skill and the task can be efficiently performed with little attention. During Phase 3, the skill becomes "proceduralized" such that once a stimulus is presented, the responses can often be prepared and executed without conscious mediation by the learner. After a substantial amount of consistent task practice, skilled performance becomes fast, accurate, and the task can often be performed with minimal impairment while attention is also being devoted to a secondary task (e.g., see Schneider & Fisk, 1982). Although improvements in performance during practice are still found at this final level of skill acquisition, practice functions at this stage are well described in terms of diminishing returns, in keeping with the Power Law of Practice (Newell & Rosenbloom, 1981).

Summary. From a performance-resource function perspective, information processing that requires the use of declarative knowledge implies analogous demands for attentional resources. Thus, during the first phase of skill acquisition, great demands are placed for cognitive/attentional effort. Such effort is necessary for enabling adequate task performance, as well as for development of later-phase skills. As a learner acquires skills (through knowledge compilation and proceduralization), the demands on the attentional system are markedly reduced, freeing resources for other activities. At asymptotic levels of skill acquisition (complete proceduralization), the task can be performed with few (if any) attentional resources. This level of skilled

¹ Although consistency is operationalized somewhat differently for diverse types of tasks, consistency generally refers to invariant rules for information processing, invariant components of processing, or invariant sequences of information processing components that may be utilized by a learner to attain successful task performance (see Fisk, Ackerman, & Schneider, 1987).

performance is characterized as "automatic." Briefly, when tasks demand the use of declarative knowledge, performance is essentially resource-dependent (as in Figure 1). When the skill is proceduralized, performance becomes resource-insensitive (as in Figure 2).

Attention and General Intelligence

In addition to providing a mechanism for understanding the effects of consistency and practice, the performance-resource function exposition may be used as a springboard for describing an individual-differences approach to abilities and task performance. Norman & Bobrow (1975) describe resources as portions of a person's attentional capacity. Slightly modified, the concept of these attentional resources also may be used for considering individual differences (Ackerman, 1984, 1987). From this perspective, any person's performance may be represented as a joint function of the person's relative attentional/cognitive capacity (i.e., relative to the population) and the proportion of the person's total capability actually devoted to the task. In this sense, the performance-resource function designation may be translated into a *Performance-Ability Function*. Given a direct equating between a person's general intellectual ability and his/her level of attentional functioning (e.g., see Ackerman, 1986a, 1986b, 1987, Zeaman, 1978), ability differences may be translated into individual differences in attentional resources. The resource demands of a task, and the relations between resources and performance may be thus mapped onto the relations between abilities and performance. From this perspective, resource-dependent tasks are anticipated to be "ability-dependent," and resource-insensitive tasks are similarly expected to be "ability-insensitive."

If attention is to be considered roughly equivalent to intelligence, then amount of attention may be equated with the level of (or amount of) intelligence. Leaving aside the influence of motivational determinants of effort for the moment, differences in task performance attributable to amount of attention allocated to the task are conjectured to be analogous to differences in performance attributable to individual differences in level of intelligence. In addition, there is a correspondence between the attentional requirements of information processing tasks and the degree of association between general intellectual abilities and task performance. It follows that this perspective allows for an extension to predicting relations between intellectual abilities and skill acquisition during skill acquisition.

Intelligence & Learning

Intelligence can be viewed as composed of many facets, or can be defined as a global concept. For example, one theorist (Buckingham, 1921) suggested simply that intelligence "is the ability to learn." However, the key concept for this and many other definitions of intelligence regards *adaptation* of the individual to the demands of the environment. From a broad perspective, approaches to defining and measuring intelligence have been concerned with assessing the mechanisms for learning and the results of learning (whether in terms of declarative knowledge -- i.e., knowledge about things, or procedural knowledge --i.e., knowledge of how to do things).

Given that learning is a major aspect of any theoretical conception of intelligence, substantial attention has been devoted over the years to establishing empirical connections between the two constructs. Three questions have been central to providing an understanding of learning and intelligence. These are: (a) How does intelligence come about; (b) How does intelligence influence learning; and (c) How is intelligence related to efficacy of information processing subsequent to learning? A

great deal of research has been devoted to the developmental aspects of intelligence acquisition (for example, see Hunt, 1961). The central focus for the current chapter, though, will be with the latter two questions.

For adults, intelligence (whether general or specific) is seen as the foundation upon which all new information is processed by any given individual. As Ferguson (1954, 1956) pointed out, the key to understanding learning is that the process is accumulative, where each new fact or procedure incorporated is partly a result of prior and present knowledge. In fact, Ferguson maintained that *transfer* is implied in nearly all learning.² That is, learning in the absence of some aspect of transfer is an extremely rare occurrence (such as only with the neonate). Given this fundamental implication of intelligence influencing future learning via transfer, it is sensible to ask specifically how intelligence interacts with learning.

There are many cases where demonstrative associations between intelligence and learning are found in the literature (e.g., see Estes, 1982; Zeaman & House, 1967). Unfortunately, in many situations, measurement (i.e., statistical) problems are associated with assessing amount of learning, independent of initial level of performance (see Cronbach & Furby, 1970). First of all, what has been determined to date is that intelligence is strongly associated with initial performance on most skill acquisition tasks (Fleishman, 1972). However, more striking is the fact that on many learning tasks, the influence of intelligence on task performance seems to markedly attenuate as time-on-task increases. Ackerman (in press) has theorized that a complex, but tractable, relationship is found between intelligence and performance under learning conditions. This theory states that intelligence is crucial for development of the declarative knowledge representation that occurs for novel tasks (i.e., Phase 1) - that is, when there is less potential for transfer of training. The importance of intelligence in learning is thus found when new production systems are established, such as the selection of appropriate task strategies. Similarly, intelligence is also important for two other declarative knowledge aspects of skill acquisition; the modification or enabling of previously learned information processing structures.

However, once the appropriate strategies are selected, production systems established, and so on, the influence of intelligence on future learning substantially changes (as a learner moves beyond Phase 1 of skill acquisition). Basically, when the consistent rules and procedures are internalized by the individual, further learning (to levels of asymptotic performance) is associated with abilities other than general intelligence. As has been argued elsewhere (Ackerman, in press), abilities that have greater involvement of speeded information processing correlate with later phases of skill acquisition. Specifically, perceptual speed abilities are most closely associated with performance individual differences in Phase 2 (knowledge compilation) and psychomotor abilities are associated with Phase 3 skill individual differences (proceduralized skills). For details, see Ackerman (in press).

Intelligence and Information Processing after Learning

That intelligence is implicated during learning is not surprising. However, the fact that intelligence is seen as the foundation for building production systems, *but not in the post-learning phases of operation* is an important aspect of the human

² Transfer, whether of knowledge, skills, prior training, processing mechanisms, and so on, is the concept of building upon a structure provided by earlier learning experiences (Woodworth, 1938).

information processing system. As William James, A. N. Whitehead, and many others have pointed out, normal human functioning involves very little that may be described as 'intellectual,' 'requiring thinking,' and so forth. Instead, much of normal human mental activity is more like a series of 'flywheels' (James, 1890; Reason & Mycielska, 1982). Series of production systems are established, tuned, and ultimately unitized, so that a long series of productions may be triggered by a single stimulus or internally generated intention (such as reaching for a fork at the dinner table, or putting on one's socks). Intelligence is the stuff of which these production systems are created (or modified from previous uses).

Subsequent to the lengthy process of learning, intelligence (or attention) is only needed when series of production systems must be modified (such as driving an unfamiliar car), added to (as when an electronics troubleshooter encounters a more complex system), or when greater-than-normal accuracy is needed (e.g., taking apart a clock vs. taking apart the same clock when it is connected to a time-bomb). In such cases, intelligence is used to provide additional checking on the information processing system in order to preserve stricter tolerances.

Motivation and Attention

Overview. Motivational processes represent an important but often overlooked determinant of learning and the expression of intelligence (Dweck, 1986; Snow, 1986). Recent trends in motivational psychology, conceptualizing motivation as a dynamic state rather than a trait, have fostered the development of an integrated view of personality, motivational and cognitive determinants of learning and performance (e.g., see Atkinson & Birch, 1970; Carver & Scheier, 1981; Humphreys & Revelle, 1984; Kuhl, 1981; Maehr, 1986; Weinert & Kluwe, 1987). In the dynamic, integrated models of motivation, learning and performance depend on the interactions between the learner, situational factors, and the learner's behaviors (Bandura, 1986; Kanfer, 1986). Such a perspective requires consideration of the interactive effects of cognitive and noncognitive individual differences and learning environments.

Motivation is generally assumed to involve regulation of one's activities with respect to three components: (1) *direction* of behavior; (2) *intensity* of effort, and (3) *persistence* of effort over time (Campbell & Pritchard, 1976). Recently, several theorists have conceptualized motivation as a cognitive resource allocation process (e.g., Humphreys & Revelle, 1984; Kanfer, 1987; Kanfer & Ackerman, submitted; Kleinbeck, 1987; Naylor, Pritchard, & Ilgen, 1980). In these approaches, cognitive and motivational paradigms are brought together by defining motivation as the processes underlying allocation of limited cognitive resources, or attentional effort. In this view, direction refers to the *focus* of attentional effort; intensity refers to the *proportion* of one's total attentional effort directed toward the task; and persistence refers to the extent to which attentional effort toward the task is *maintained over time*. A definition of motivation that emphasizes the regulation of cognitive resources limited by individual differences in attentional capacity, recasts motivational phenomena into a framework that allows for integration of motivational and ability approaches to learning.

In Kanfer (1986, 1987) and Kanfer and Ackerman's (submitted) resource formulation, motivational mechanisms affecting learning and performance are organized into two distinct resource allocation processes. Distal resource allocation processes guide the individual's behavioral intentions and choice among goals. Persons develop specific intentions (e.g., to learn a new skill) and choose specific behavioral objectives (e.g., to obtain a specific performance score). The resource allocation process

underlying the development of these conscious intentions and goals are termed *distal*, since their effects on learning depend on how the intentions and goals are implemented in action. Information processing demands imposed by the task, individual differences in abilities and self-regulatory processes, represent additional determinants of learning that influence the extent an individual's goals are realized in behavior.

The second source of motivational effects stems from the resource allocation processes translating intentions and goals into action. These resource allocation processes are referred to as *proximal* motivational determinants, since their operation has direct consequences for learning. Motivational processes at this point refer to cognitive, self-regulatory activities that direct, energize, and sustain attentional effort involved in learning. Distal allocation processes influence the individual's choice among potential goals. In contrast, proximal motivational processes operate in the context of competing demands for attentional effort. Such demands are imposed by the task and by limitations of resource availability attributable to individual differences in ability. Metacognitive activities that increase or decrease allocations of attentional effort to task components affect performance on resource-dependent tasks.

The determinants, consequences, and evidence for the operation of distal and proximal motivational processes on performance are described in greater detail below.

Distal Determinants of Effort Allocations

Expectancy-Value theories have emerged as the most powerful approach for examining the determinants of an individual's intentional effort allocations (Atkinson & Feather, 1966, Campbell & Pritchard, 1976; Feather, 1982; Mitchell, 1982). The basic assumption of these theories is that persons try to maximize positive and minimize negative outcomes. Goal decisions and intentions to allocate attentional effort are made on the basis of anticipated costs and benefits (Mitchell, 1974; Vroom, 1964). In particular, individuals must make judgments of the potential benefits of increasing attentional effort to attain higher levels of performance and the associated costs of increasing effort. These judgments appear to depend on three cognitive mechanisms: (1) the *utility of performance*, (2) the *utility of effort*, and (3) the *perceived effort-performance function*.

The utility of performance. The attractiveness of allocating effort toward performance includes consideration of both extrinsic or intrinsic benefits anticipated for different levels of performance (Naylor, et al., 1980). Performance levels associated with acquisition of desired material rewards, recognition, and/or feelings of competence are viewed as attractive. Dispositional factors, such as achievement orientation, can affect the relative attractiveness of the different outcomes associated with learning and higher levels of performance. Moreover, different levels of performance may be more or less attractive, depending on the constellation of outcomes associated with each level of performance. Beginning math students, for example, may perceive test scores of 60, 70, and 80 as similarly attractive (due to their associations with a passing grade) but may view scores of 85 through 100 as increasingly more attractive, if these scores are additionally associated with increasing levels of public recognition and pride. According to Naylor et al. (1980) and Kanfer (1987), the overall utility of performance is cognitively represented as a contingency function between performance levels and the anticipated attractiveness of all outcomes associated with varying levels of performance.

The utility of effort. Individuals must also evaluate the anticipated costs and benefits of task-specific effort allocations in terms of the individual's preference for

effort expenditure. Research on arousal and anxiety suggests an inverted U-shaped function between attentional effort allocations and positive affect. Persons performing tasks that require little attentional effort frequently report low satisfaction with the work and describe the work as boring. Persons performing tasks requiring very high effort allocations over time often describe the work as stressful and fatiguing (similarly unattractive). In addition, recent evidence from the individual differences domain suggests the existence of relatively stable individual preferences for specific levels of effort expenditure (Spence & Helmreich, 1983).

The perceived effort-performance relation. A third motivational mechanism concerns the individual's subjective estimate of the effort - performance (E-P) relation. The perceived E-P relation reflects the individual's perception of the performance resource function for the task in question. According to Kanfer (1987), the E-P function enables individuals to *translate* performance levels into personally meaningful effort allocations and thus serves a critical informational function. Without this referent relation, decision-making to maximize overall utility is likely to be imprecise at best. For example, although persons may view increased performance as desirable, the perceived E-P function enables persons to judge whether the costs of effort to attain the desired performance override the benefits of improved performance. When persons perceive the effort requirements of performance to exceed their capacity, motivation is not likely to increase unless extremely powerful incentives are offered for higher levels of performance.

Determinants of Distal Motivational Processes. Findings in the Expectancy-Value and goal setting literature indicate that both dispositional and contextual factors influence goal choice and behavioral intentions (see Mitchell, 1974; Locke, Shaw, Saari, & Latham, 1981 for reviews). These factors are based on the perceived attractiveness of various outcomes associated with specific performance levels and subjective estimates of the effort-performance function. For example, need for achievement and fear of failure represent dispositions affecting the salience and attractiveness of outcomes. These traits have been reliably shown to influence choice of preferred level of task difficulty (see Feather, 1982). Past performance success (e.g., Feather, 1966), expectations of success (e.g., Mento, Cartledge, & Locke, 1980), monetary incentives (e.g., Terborg, 1976; Terborg & Miller, 1978), social incentives (e.g., Latham & Saari, 1979), competition (e.g., Latham & Baldes, 1981), and the presence of evaluative/normative information (e.g., Mitchell, Rothman, & Liden, 1985) have also been shown to influence goal choice, effort intentions, and/or task performance. Direct instruction and goal assignments represent particularly powerful situational factors influencing intended effort allocations. Goal-setting research indicates that explicit, difficult goals facilitate performance on simple, well-learned tasks (see Locke, et al., 1981; Mento, Steel, & Karren, 1987; Tubbs, 1986).

Another influence on goal choice and intentions stems from individuals' perceptions of the E - P function. Objective task characteristics, such as task type, have been shown to affect expectations of task success (e.g., Kirsch, 1982; Jackson & Zedeck, 1982). Kirsch, for example, found that persons engaged in a difficult paper-toss task, involving skills not readily perceived to be under volitional control, were less likely to alter expectations of task success under heightened incentive conditions compared to persons engaged in a snake approach task - a task more likely to be perceived as under volitional control. In the attentional resource framework, performance on the paper toss task would likely be perceived as effort-insensitive whereas performance on the snake approach task would likely be perceived as effort-dependent. These different perceptions of the performance resource function appear to moderate the motivation - performance relation.

Summary. Distal motivational processes involve allocation of cognitive/attentional resources on the basis of the joint operation of three cognitive mechanisms; (1) the performance-utility function, (2) the effort-utility relation, and (3) the perceived E-P relation (Kanfer, 1987). The thrust of these approaches has been to predict the effects of motivation on goal choice and performance rather than learning. As a result, individual differences in ability that may mediate the goal - performance relation tend to be neglected in these formulations. As several authors note (e.g., Mitchell, 1982, Kanfer, in press; Kuhl, 1986) Expectancy-Value conceptualizations appear best-suited to prediction of an individual's conscious and rational choice among distinct alternatives courses of action, such as preference among a choice of tasks. To understand how motivation affects learning, it is necessary to extend motivational models to include the translation of goals into action.

Proximal Determinants of Attention

The establishment of goals through distal resource allocation processes results in direction of attentional effort toward goal attainment. When goals are readily attainable or anticipated to be easily attained, no further motivational processing is likely to occur. Daily choices, such as what to wear and when to arrive at work, involve goal choices that are generally realized quickly and without difficulty. However, in complex skill acquisition, goal attainment typically requires sustained attentional effort in the face of difficulties. Additional volitional, or metacognitive activities that guide resource allocations during the prolonged period of learning and execution of intentions are required to maintain sustained attentional effort (Bandura, in press). In contrast to distal approaches, motivational processing at this point can have a direct influence on rate and asymptotic level of skill acquisition.

Self-regulatory activities. Motivational activities in self-regulation are typically divided into three key groups: *self-monitoring*, *self-evaluation*, and *self-reaction*. The importance of these functions in the self-regulatory system and in the control of specific patterns of behavior have been demonstrated in numerous studies of learning and performance (see Bandura, 1977; 1982; Kanfer, 1977).

Self-monitoring, or self-observation, refers to the individual's allocation of attention to specific aspects of his/her own behavior. The basic notion is that individuals cannot continuously attend to all aspects of their behavior (Bandura, 1982, 1986). As a consequence, persons selectively attend to particular dimensions of behavior based upon the salient features of the activity, valuation of behavioral outcomes, and the functional significance of the activity for attainment of goals. Self-monitoring may occur in response to external or internal prompts. When performance outcomes are very important, for example, individuals may increase self-monitoring and allocate more attention to observing performance outcomes.

Furthermore, self-monitoring (i.e., attending to dimensions of performance corresponding to one's performance goals) is necessary for the operation of *self-evaluation* functions that influence attentional effort expenditures. Note, however, that attention to components of one's behavior is not synonymous with accurate assessment of one's performance.

Self-evaluation. Self-evaluation involves a comparison of the desired goal state with current performance. In this cognitive comparison process, individuals check their progress against a standard or referent. The size and direction of the goal - performance discrepancy influences subsequent decisions regarding allocation of attentional effort. Large goal - performance discrepancies often indicate that

substantial effort will be required for goal attainment.

Self-reactions. Bandura's theory (1986) indicates that observation of one's performance in the context of goal-directed behavior exerts two independent effects; those on self-satisfaction and those on perceptions of self-efficacy. Goal - performance discrepancies give rise to affective reactions of satisfaction/dissatisfaction and perceptions of self-efficacy. Judgments of satisfaction/dissatisfaction represent self-generated affective consequences of self-evaluation. When goal - performance discrepancies are small, individuals are satisfied and self-regulatory processing may be disengaged. In contrast, when goal - performance discrepancies are moderate or large, dissatisfaction is high and motivational force is maintained to reduce the discrepancy. If individuals perceive themselves to be sufficiently capable of attaining the goal (i.e., high self-efficacy), dissatisfaction may yield a decision to simultaneously increase attentional effort to the task and sustain self-regulatory processing (Bandura & Cervone, 1986).

Bandura's social cognitive theory expands self-regulation models to include self-efficacy expectations. Self-efficacy expectations refer to the individual's beliefs about his/her capabilities for attainment of specific task behaviors and are functionally similar to perceptions of the effort-performance function. Initial levels of perceived self-efficacy develop from a variety of sources, including past performance, social comparisons, and vicarious learning. During learning, self-observation of progress refines self-efficacy judgments and thus alters the way in which perceived goal - performance discrepancies are handled (Bandura & Cervone, 1983). The two self-reactions, self-efficacy expectations and self-satisfaction, jointly influence attentional effort allocations (Bandura 1977, 1986). When confidence in one's capability for goal attainment is high and self-dissatisfaction is moderate to high, persons are presumed to allocate greater attentional effort toward task performance. However, when dissatisfaction is high and confidence is low, attentional effort may be shifted away from task performance. Self-regulatory processes that result in increased attentional effort toward task performance enhance learning; processes that result in decreased attentional effort directed toward task performance are expected to impair learning.

Summary. The resource allocation approach to motivation described above distinguishes between motivational factors affecting (a) an individual's decision to exert effort toward goals and, (b) motivational processes involved in translating intentions into performance. Proximal resource allocation processes follow the formation of an intention or establishment of a goal. In contrast to distal processes, which emphasize the individual's attempts to maximize positive utility, proximal processes involve self-regulation of attentional effort for the attainment of a specific goal. The implementation and operation of these self-regulation processes will vary depending upon dispositions and situational factors. The effectiveness of self-regulatory activities in sustaining effort and controlling behavior over time has been well-documented. In many of these investigations, however, the target of self-regulatory activities is change in the frequency of previously learned behaviors or the development of passive responses to stimuli associated with immediate rewards. In contrast, learning involves the development of active responses to stimuli often associated with long-term rewards. Considerably less is known about how proximal motivational processes affect complex skill acquisition in learning environments.

Motivational Processes and Learning

A central feature of the resource conceptualization of motivation is the

distinction between distal and proximal resource allocation processes. Distal motivational processes influence the establishment of goals and intentions. These processes typically occur prior to, or independent of, task engagement. Attentional effort required for making goal decisions is thus unlikely to compete with attentional demands imposed by the task. In contrast, proximal resource allocation processes occur during learning. *In general, these proximal motivational processes compete with task demands for available cognitive resources.* This suggests that there may be cognitive costs (in terms of attentional effort resources) associated with proximal motivational processes.

Two studies provide evidence for the assertion that self-regulatory activities demand attentional effort. F. Kanfer and Stevenson (1985) examined the effects of engaging in self-regulatory activities while performing an information-processing task. Subjects performed the Continuous Paired Associate Task (CPAT) under low, moderate, or high task difficulty conditions. In addition, all subjects performed a secondary task. Subjects assigned to the self-regulation secondary task condition were instructed to provide responses to self-monitoring, self-evaluation, and self-reaction questions at regular intervals during rehearsal of primary task stimulus items. Questions in the Self-regulation condition pertained to self-regulatory activities associated with performance on the CPAT task. In the Math control condition, subjects completed a simple arithmetic problem. In the Delay control condition subjects were given feedback but did not answer any questions. As expected, CPAT performance in the Self-regulation condition was similar to performance attained in the Math condition, with both the Math and Self-regulation groups performing significantly lower than the Delay condition. In learning contexts, where the task imposes initially high attentional demands, the cognitive costs of engaging in self-regulation may hinder, rather than facilitate task performance.

Kuhl and Koch (1984) reported results further supporting the notion that self-reactions and cognition related to self-evaluation may reduce attentional resources available for task learning. In this study, dispositional tendency toward state-oriented (task-irrelevant) cognition such as self-evaluation, and action-oriented cognition (task-relevant), were assessed via questionnaire at the beginning of the session. Immediately prior to training, level of motivation was manipulated by asking subjects in the high motivation condition to solve a "master-mind" problem, but interrupting the subject prior to task completion. Subjects in the low motivation condition were asked to read a story. Kuhl and Koch (1984) found that state-oriented subjects performed more poorly than did action-oriented subjects on early performance of a tracking task under low motivation condition. Kuhl and Koch suggest that the lowered performance of state-oriented subjects was due to their performing a "hidden second task" (p. 151) in which attentional effort was directed toward emotional, or off-task thoughts.

Summary. The Kuhl and Koch (1984) findings indicate that task-irrelevant cognitions impose demands on attention. These demands were, in turn, associated with reductions in learning efficiency in a complex motor task. Self-regulatory processing contains similar off-task cognitive processing in terms of self-evaluation and self-reactions. Results obtained by Kanfer and Stevenson (1985) indicate that engaging in self-regulatory activities reduced learning efficiency on a cognitively demanding information-processing task. Taken together, these studies strongly suggest that self-regulatory activities are resource-consumptive. When cognitive task demands are high, motivational interventions that trigger proximal self-regulatory activities may be expected to impair task performance.

The resource costs of self-regulation during cognitively demanding phases of skill

acquisition refer to the costs of directing attentional effort toward self-regulation activities *per se*. The *products* of self-regulatory processing represents a further resource allocation process that may aid learning, depending upon the extent to which the allocation process ultimately increases on-task attentional effort (Kuhl, 1986). Self-regulation processing that results in an *increase* in on-task attentional effort may compensate for the cognitive costs of self-regulation. Self-regulation processes that direct attentional effort toward the reduction of emotional, "off-task" activities (e.g., calming oneself down in a stressful situation) may reduce on-task effort resources but still result in more rapid learning than would be obtained when attentional effort to off-task activities is unregulated.

Motivation and Performance

The efficiency of motivational processes in skill acquisition depends upon the joint influence of: (1) demands on attentional effort, (2) self-regulatory processing, and (3) an individual's goals. When attentional demands of the task are high, self-regulation activities reduce on-task attentional effort and should decrease task performance. During the declarative phase of skill acquisition, attentional task demands are continuous and high. In this phase of learning, the engagement of self-regulatory activities should reduce cognitive resource availability for task performance.

A second factor influencing attentional effort for task performance is the product of self-regulatory processing. Self-regulatory processing affects allocation of attentional effort to on-task and off-task activities. Self-regulation that increases allocation of attentional effort to the task, may, in effect, compensate for reductions in resource availability due to the initiation of self-regulatory activities. When self-regulatory processing results in greater availability of resources for task performance, performance should be enhanced.

The product of self-regulatory processing depends, in turn, on the individual's goals. Goals established in distal motivational processing may be roughly distinguished in terms of their emphasis towards on-task or off-task orientations. Task-related goals (such as attainment of specific performance criteria), refer to intentions related to task behavior. Off-task goals, (such as "demonstrating competence"), refer to intentions related to emotional well-being.

An individual's goal orientation provides for selection of various self-regulatory strategies and thus determines the product of self-regulatory activities. As Locke et al. (1981) indicate, explicit difficult and specific performance goal assignments influence intentions and direct attention toward task performance. When individuals adopt appropriate task-related goals, the product of self-regulatory processing should optimize allocation of attentional effort toward task performance. In contrast, adoption of off-task goal orientations should result in diversion of attentional effort away from the task and towards off-task concerns.

The resource-based analysis of motivation identifies basic motivational processes in terms of their information-processing implications. The effects of these processes on learning and performance, however, must be considered in light of individual differences in ability. Researchers typically focus on *either* motivational *or* ability determinants of performance despite the long standing belief that performance is determined by the *joint* effects of motivation and ability (Vroom, 1964). The approach to be used here builds upon and extends prevailing theories of individual differences in ability, information-processing theories of performance, and theories of task motivation to describe an integrated resource-based theory of ability/motivation interactions.

during skill acquisition. Using this theory, predictions of ability/motivation interactions in skill acquisition are derived and empirically tested.

Summary of the Foundation

Although motivation and intelligence have traditionally been thought of as divergent constructs, if not actually incommensurable, the preceding discussion provides a method for explicitly integrating the concepts, via consideration of the construct of attentional resources. From these arguments, several major points can be made. Specifically:

1. Attentional/cognitive resources are conceptualized as an amorphous pool, representing the limited capacity of the human information processing system.
2. Information-processing tasks can be described as resource-dependent or resource-insensitive.
3. As learners acquire task performance skills, the character of a task changes from predominantly resource-dependent to resource insensitive (corresponding to changes from declarative and procedural knowledge bases for skilled performance).
4. Ability/performance correlations (and theoretical developments) allow for a rough equating of individual differences in general intellectual abilities with analogous differences in cognitive resource *capacity*.
5. Decisions of what proportion of attentional capacity an individual devotes to a task are based on an implicit utility analysis of two *distal* components (the performance-utility function and the effort-utility function), which is moderated by the perceived effort-performance function.
6. In dynamic performance situations (such as learning), variations in resource allocations come about through the influence of self-regulatory processes (i.e., self-monitoring, self-evaluation, and self-reinforcement).

III. A MODEL OF ABILITY/MOTIVATION INTERACTIONS

Portions of the attentional resource approach can be illustrated with a hydraulic representation, as shown in Figure 3. This structure of attentional resources is closely related to a model proposed by Kahneman (1973, see his figure 1-2). In particular, we have endorsed Kahneman's use of a flexible allocation of attentional capacity, a policy mechanism for distributing attention across different activities, feedback loops for adjustment of allocation policy and proportion of total capacity allocated, and for both external influences at the level of allocation of capacity and allocation policy. However, there are a few important alterations and additions, as noted below.

Insert Figure 3 about here

First of all, our representation explicitly distinguishes among three types of possible activities: (a) off-task activities, (b) on-task activities, and (c) self-regulatory activities. Rather than providing a separate mechanism (outside the consumption of attentional resources for "evaluation of demands on capacity," our self-regulation component serves this same purpose, *while also demanding attention*. Finally, we explicitly distinguish between distal (e.g., effort-utility and performance-utility functions) and proximal processes (e.g., goal-setting, the results of self-regulation), and provide for individual differences in amount of attentional resource capacity (i.e., ability level).

One assumption underlying this model is that changes in the amount of capacity utilized and policies for allocation of attention are accomplished through motivational processes. Under this rubric, the learner assesses attentional demands imposed by the task, and by subsidiary processes (off-task and self-regulation overhead) via self-regulation. Over time, self-regulatory processes are used to re-allocate attention or to mobilize additional portions of capacity to the various activities. When task resource demands are high, the learner may re-allocate more available attention to the task, or may seek to adjust the proportion of capacity engaged. Conversely, when task resource demands are reduced, the learner may seek to attend to off-task activities, or reduce the proportion of capacity engaged. A primary assumption of the model is that self-regulation is an important mechanism used to bring about changes in allocation policy towards a task or total proportion of resources engaged. Without activation of self-regulatory processes, a learner would be expected to devote to a task the amount of resources originally committed via distal processes. In terms of task performance, though, a possible drawback to activation of self-regulatory processes is that such processes draw away from resources available to the task. If the drain on resources cannot be made up through decreasing the amount of resources devoted to off-task concerns, or by increasing the proportion of capacity available, then resource-dependent tasks will show a decrement in performance. Conversely, a drain of resources by self-regulation for resource-insensitive tasks will not result in a decrement in performance (by definition).

Individual differences in ability level/resource capacity will determine the amount of flexibility in amount of resources that can be devoted to any set of activities. Consistent with the graphic representation in the figure, low-ability learners must devote a greater portion of their capacity than high-ability learners in order to achieve the level of task performance.

This representation *as shown* though, is static. Changes in the performance-resource function that occur during the acquisition of skills (changes from declarative to procedural knowledge) are not directly represented in the figure. The implication is that changes in the true performance-resource function will be detected by self-regulatory processes (i.e., self-monitoring). When the task becomes less resource-insensitive, learners will discover that fewer resources need to be devoted to the task to maintain performance. As such, resources may be diverted to other activities, including additional self-regulatory processing, or the learner may choose to reduce the proportion of capacity currently engaged. To the degree that self-regulatory activities are beneficial to acquisition of skills, the decreasing task resource demands may serve to feed self-regulation, and thus accelerate task performance improvement.

Implications of the Ability/Motivation Model

There are numerous implications of this integrated framework of ability/motivation determinants of skill acquisition and performance. However, it is our intention to focus here on a few of the more salient features of the model that relate to interactions between intelligence and motivational manipulations on the development of skilled performance. In particular, consider the following inferences from the model.

Let us start with a novel task that has high resource demands (i.e., performance is resource-dependent throughout the ability range, and prototypically more so for low ability learners - e.g., see Figure 1). As such, the intelligence/performance correlations will be moderately to highly positive for initial performance, but decline with task practice (as learners move from declarative to procedural knowledge). Let us also consider the effects of a motivational (goal-setting) manipulation that triggers

self-regulatory activities. Recall that self-regulatory activities also demand attentional resources. Thus, in contrast to a control condition, performance will be decremented on the task with an imposed goal. (When the task requires all available resources, there is no spare capacity to mobilize, and thus there is no increased task effort product of self-regulation.) Moreover, if a steeper slope of the performance-resource function is found at lower levels of attention (ability), we further expect low ability learners to demonstrate greater impairment in performance than high ability learners. In keeping with the broader literature (e.g., Snow, *in press*), the implication, then, is for a demonstration of aptitude-treatment interactions.

On the other hand, consider a task that has reduced resource demands (e.g., a task that is no longer novel, such that the declarative knowledge portion of the skill has already been developed). In addition, consider the effects of a goal-setting manipulation that leads to self-regulatory activities. In contrast to the previous condition, the instigation of self-regulation is not associated with a drop in performance for either high or low ability learners (given that Phase 2 activities *demand* fewer resources). Furthermore, since there are spare resources available, the increased task effort product of self-regulation can be put directly to use towards task performance. Nevertheless, the high-ability learners are presumed to be at a more resource-insensitive portion of the performance-resource function than are low-ability learners. Thus, an aptitude - treatment interaction is predicted in this scenario as well. However, *note that the prediction differs markedly from that in the initial scenario*. That is, when the task resource demands are high, self-regulatory activities lead to decrements in performance, with low-ability learners being more negatively impaired by self-regulation, as compared to high-ability learners. When the task is sufficiently learned to reduce resource demands, self-regulatory activities lead to increments in performance, with low-ability learners being more positively affected by self-regulatory activities.

IV. OVERVIEW: EXPERIMENTS COMPLETED UNDER THE GRANT

Description of the Task Paradigm

The Air-Traffic Controller (ATC) task is a rule-based, real-time computer-driven task that simulates some of the activities performed by air-traffic controllers. The major restriction of our instantiation of the task is that the spatial information processing demands are severely limited (no graphics are used in the task). The overall objective for learners is to land planes safely and efficiently.

A prototypical (albeit static) screen display of the ATC task is presented in Figure 4. As shown, the following task elements are displayed when performing the task: (a) four runways, (b) 12 hold pattern positions, and (c) a queue stack with asterisks indicating planes requesting permission to enter the hold pattern. Two runways run North-South; two runways run East-West. One North-South and one East-West runway is short; one North-South and one East-West runway is long.

Insert Figure 4 about here

The hold pattern, located in the middle right section of Figure 4, contains twelve hold pattern positions, divided into three levels (analogous to three platters at different altitudes in the sky over the airport). Hold pattern position is indicated by number and letter in the Position (POS) column. Level 1 hold positions have the

lowest altitude (i.e., closest to the ground) and Level 3 hold positions have the highest altitude (i.e., are furthest from the ground). Four positions, corresponding to the points of the compass (i.e., N, S, E, W), are available in each Level.

Planes are admitted to the hold pattern from the Queue stack. The Queue, located at the upper right of the screen, displays planes requesting permission to enter the hold pattern. Each plane request is represented by an asterisk. Planes enter the Queue at the rate of one every 7 sec. Plane requests remain in the Queue until the learner places the plane in the hold pattern. Learners are told that planes in the Queue should be handled as soon as possible.

Plane information is also displayed in the hold pattern. As shown in Figure 4, four types of planes enter the learners' hold pattern; 747's, 727's, DC10's, and Props. When a plane is placed in the hold pattern, Flight Number (FLT#), Plane Type (TYPE), and Number of Minutes of Fuel remaining (FUEL) are displayed. Within each trial an approximately equal number of plane types are randomly drawn for the Queue. Fuel remaining is determined when the plane is brought into the hold pattern, and is randomly varied from four to six minutes. Once the planes enter the hold pattern, fuel remaining decreases in real time, such that when zero minutes of fuel remain, the plane crashes.

Learners also receive information on airport weather conditions. Weather information is used (in accordance with the rule set) to determine what planes are allowed to land on which runways. Weather conditions are comprised of three elements; Wind Speed, Wind Direction, and Ground Condition. Wind Speed and Wind Direction information is displayed on the "Wind" line at the top right corner of the screen. Ground Condition is displayed on the "Runways" line. Updates to weather conditions are displayed throughout each task trial. Three levels of wind speed are presented; 0 - 20 knots, 25 - 35 knots, and 40 - 50 knots. Four levels of wind direction are displayed; North, South, East, and West. Three levels of ground conditions are used; runways Dry, Wet, or Icy. Changes in weather conditions (defined as a change in at least one of the three weather condition components) is varied randomly during a task trial. On average, these changes occur about twice a minute (i.e., 20 weather changes are displayed during each 10-minute task trial).

Feedback/Knowledge of Results

The first component of Knowledge of Results is the one-to-one mapping between keystrokes made by the learner, and operation of a cursor on the screen. As planes are selected, various parts of the display are highlighted. When a plane is moved from one hold position to another, or to a runway, the learner sees an analogous change to the display. Learners also receive three types of continuously updated performance information throughout each trial. Cumulative performance (Score) for the current trial is based upon a specified point scheme. Learners receive 50 points for each plane successfully landed. Ten points are deducted for each technical error made (violation of the rules). One hundred points are deducted from the performance score for each plane that runs out of fuel in the hold pattern (i.e., plane crashes). Performance scores can be negative or positive depending on how many planes are landed, relative to number of errors made and planes crashed. In addition, learners receive separate landing (Landing Pts.) and error (Penalty Pts.) information. Landing Pts. are based only upon the number of planes landed. This score starts at zero and increases by 50 points for each plane landed. Penalty Pts. reflects the number of rule violations and plane crashes. This score starts at zero and decreases for each error. All learners are informed of the point scheme in the initial task instructions.

Task Rules

For the experiments described below, six rules govern task performance (shown in Figure 5). These rules describe the conditions required for successful manipulation of planes. When learners perform actions that do not comply with a rule, the action command is ignored, an error message is presented on the screen indicating which rule is violated, and 10 points are deducted from the cumulative and penalty point scores. Rules 1 and 4 describe weather condition rules for landing planes onto runways. Rule 2 requires that plane landings must be initiated from one of the four hold pattern positions in Level 1. Rule 3 governs movement of planes within the hold pattern. Rule 5 requires that planes with 3 or less minutes of fuel left must be landed immediately. A warning asterisk is displayed next to the FUEL value when remaining fuel fell below four minutes (e.g., see FLT # 122 in Figure 4). If the plane is not landed prior to a FUEL value of 3, a 10-point penalty is incurred for each minute that learners failed to land the plane. Rule 6 requires that only one plane occupy a runway at any time.

Insert Figure 5 about here

All rules, except Rule 4, describe simple, non-contingent conditions governing task performance. In contrast, Rule 4 describes a plane-contingent rule that involves both simple and complex elements (i.e., the specific ground and wind-speed conditions that must be met for landing each plane type on short and long runways). Simple, non-contingent elements of this rule address landing requirements for 747 and Props (747's can never land on short runways; props can always land on short runways). For 727's, a disjunctive rule relating wind and ground conditions regulates when these planes may legally land on short runways. For DC10's, a conjunctive wind and ground condition rule for short runway usage is imposed. Since positive task performance is based upon number of plane landings, it was to the subject's advantage to use both long and short runways simultaneously. Knowledge of the complex rules governing when 727's and DC10's could use a short runway is thus an important determinant of learning and task performance.

Learners are provided with the opportunity to call-up brief descriptions of each rule throughout all task trials. Learners are instructed to press a key corresponding to the rule they wished to view. The requested rule appears on the lower right corner of the screen for 10 seconds. Learners are free to call-up any of the rules as many times as they wish during task trials. Note, however, that calling-up a rule does not stop the simulation.

Figure 6 displays an example of the error messages. Error messages, which are displayed in the lower right hand section of the screen, appear immediately following a rule error or plane crash. Error messages are displayed until the learner completes a legal move.

Insert Figure 6 about here

At the beginning of an experimental session, all learners receive identical instruction on the ATC task. Instructions describe elements of the task, keyboard procedures for performing actions, rules governing task performance, and the scoring

scheme. Interactive instruction is provided for such keyboard response procedures as: (a) accepting planes from the Queue, (b) moving planes in the hold pattern, (c) landing planes onto a runway, and (d) initiating a rule call-up. Instructions are self-paced, but most learners complete the instructions in approximately 20 minutes.

The Task Requirements

Learners perform three principal actions: (1) accepting planes into the hold pattern, (2) moving planes in the three-level hold pattern, and (3) landing planes on appropriate runways. All three types of operations can be performed through the use of four keys on the computer keyboard. A one-to-one correspondence between keyboard and screen actions was maintained by linking each keyboard response to movement of a small cursor arrow on the screen. Specific keyboard actions taken to move a plane in the hold pattern and to place a plane on a runway result in highlighting the target plane and real-time movement of the plane across the runway. Successful performance on this task requires knowledge of the rules governing plane movements and landings as well as knowledge about how to initiate plane movements using the computer keys.

V. SERIES I - EXPERIMENT 1

Apparatus

Instructions, stimulus presentation, and response collection were implemented with Xerox 1186 microcomputers under IBM PC emulation software, with standard keyboard (numeric keyboard on the right side of the keyboard) and white-on-black cathode-ray-tube monitors. A schematic keyboard diagram and a key function diagram, indicating which keys were to be used (and the function of those keys) were placed on the right of the computer keyboard. A template, indicating rules associated with computer keys #1 - 6 was also taped above the top number row of the keyboard, to assist subjects in selecting the correct key for calling-up specific ATC rule displays.

Each subject sat at an individual microcomputer workstation, within a carrel. The carrels provided visual restriction to the subject's own display. The carrels also provided moderate sound restriction, which was supplemented with a white-noise type effect from computer cooling fan and central ventilation systems. The result was a generally undisturbed environment for the individual subjects. At the conclusion of the experiment, data were off-loaded from the Xerox microcomputers to a mainframe computer for storage and data reduction. Data collected from each subject included all self-report and performance measures as well as all keystroke responses made during each performance trial.

Subjects

Participants in Experiment 1 were 322 U.S. Air Force enlisted personnel undergoing basic training at Lackland Air Force Base, Texas (27 females). Subjects were tested in intact "flights," approximately 25-29 recruits at a time. Record keeping difficulties precluded obtaining exact age information for the subjects. However, most subjects were between 18 and 22 years old at the time of testing. (Prior to data analysis, data from a few subjects were discarded, some for a lack of ability testing records (2), and others for failure to follow task instructions (4). Finally, because a few subjects had incomplete data (e.g., computer failure, sickness), the degrees of freedom differ by as much as 2 or 3 *df* on some analyses). The final sample contained 316 subjects.

Procedure

General procedure -- all subjects. Subjects began the experiment at individual workstation carrels. Subjects first received an introduction to the session, instructions on use of the keyboard, and instructions for the ATC task. The ATC task instructions were both narrative and interactive. For the most part, subjects read about the task components, commands, rules and procedures. Interactive instruction is provided for such keyboard response procedures as: (a) accepting planes from the queue, (b) moving planes in the hold pattern, (c) landing planes onto a runway, and (d) initiating a rule call-up. Instructions are subject-paced, but most subjects complete the instructions in approximately 20 minutes.

Following instructions, subjects were told to "do your best" on the upcoming task trial, and then performed a single, 10-minute task trial. The trial was immediately followed by a brief questionnaire. The common first task trial (Trial 1) provided the baseline for assessment of pre-treatment effects.

No Goal - control condition. Following the first task trial, the No Goal control group received nine, 10-minute task trials (Trials 2 - 10). To minimize massed practice effects, subjects were given 10-minute breaks following completion of each set of three trials (i.e., after Trial 4 and Trial 7). Subjects were not allowed to discuss the task with others during the breaks. Subjects were instructed to "do your best" prior to each set of three trials. These subjects were told: *"Your objective in the next three trials is to get the best performance score you can."* Immediately following Trial 4 and Trial 10, subjects completed short computerized self-report questionnaires. After the final questionnaire, subjects and then were administered a "Rules/Knowledge Test." In this test, subjects were required to write out (with pencil and paper) the six rules governing performance on the ATC task in as much detail as possible. When subjects returned the forms they were debriefed and excused.

Early Goal condition. The procedure described for the No Goal group was repeated for the Early Goal group, with the following exceptions. Task - specific motivation was manipulated by assignment of a specific and difficult performance goal for three task trials (i.e., Trials 2 - 4). Subjects in the Early Goal condition received the goal assignment prior to Trial 2. Subjects were assigned a cumulative performance score goal of 1900 points (per trial) for Trials 2, 3, and 4. The 1900 - point goal was selected on the basis of results obtained in pilot experiments (no goal) with the ATC task. Pilot data indicated that 1900 points represented a difficult performance goal (approximately 90th percentile) for Trials 2, 3, and 4. Subjects in the Early Goal assignment condition were told:

For the next three trials, you have been assigned a specific performance goal. Your assignment is to achieve a Performance Score of 1900 points by the end of the trial. That is, on EACH of the next three trials your goal is to achieve a Performance Score of 1900 points.

In addition to the performance goal assignment, subjects in the Early Goal condition were given the opportunity to periodically check their goal progress during the three assigned goal trials. Subjects were told:

*You can check on how well you are doing by "calling up" more performance information. Several times during the trial, a special signal (***F10***) will appear at the top right of your screen. When this signal appears, you may press the F10 key to get more information about how you are doing, relative*

to the performance goal assignment.

The "F10" signal was displayed for 10 seconds for each minute of each trial (beginning 1:00 min into the trial). Subjects who pressed the "F10" key during the signal received a message at the bottom right of their screen indicating the percent of the goal they would obtain. This goal/performance feedback was calculated by extrapolating from the subject's current performance, divided by the assigned goal point total. An example of the message displayed is: *"Based on your current performance you will attain 80% of your goal."*

Early Goal subjects also completed two brief questionnaires. The first questionnaire was administered immediately following the first goal assignment, and prior to task Trial 2. The second questionnaire was completed immediately following Trial 4. Following Trial 4, no further goal assignments were given. Beginning with Trial 5, all subjects in the Early Goal condition were instructed to "do your best."

In order to simplify administration of the experiment, goal condition (No Goal vs. Early Goal) was manipulated by flights of subjects who participated in the experiment at the same time (Early Goal $N = 149$; No Goal $N = 167$).

Dependent Measures

Ability measures. Estimates of cognitive/intellectual ability were derived from a composite based on the ten test, Armed Services Vocational Aptitude Battery (ASVAB). The ASVAB was completed by the subjects several months prior to the experiment and test scores were obtained from personnel records. A global estimate of cognitive ability (general intellectual ability) was obtained using a unit-weighted composite based on all 10 subscales of the ASVAB.³ Subjects were then divided into high ability and low ability groups using a median split on the ability composite. This split was used as a two-level blocking factor in ANOVAs reported below. For separate ability analyses (General and Perceptual Speed factors), a hierarchical factor solution was derived from the ASVAB data.

Goal-related measures. Subjects in the Early Goal condition completed brief self-report questionnaires immediately following the goal instructions and again immediately following the last assigned goal trial. The first questionnaire contained five, 8-point Likert-scale questions, assessing goal commitment and self-confidence in goal attainment. In addition, subjects were asked to predict the performance score they thought they would obtain on the next task trial (i.e., Trial 2).

To assess the effectiveness of the goal manipulation on self-regulatory processing, six, 8-point Likert-scale items (1 = Never; 8 = Constantly) were administered immediately following the final goal trial (i.e., Trial 4). Four items, assessing attention to the goal, were summed to form a composite goal attention scale score. Two items, assessing frequency of performance monitoring, were summed to provide a composite performance monitoring scale score.

Self-reports of cognitive/conative activities: Trials 8 - 10. Subjects in the No

³ The ASVAB is composed of the following sub-tests: General Science, Arithmetic Reasoning, Word Knowledge, Paragraph Comprehension, Numerical Operations, Code Speed, Auto Shop, Math Knowledge, Mechanical Comprehension, and Electronics Information.

Goal and Early Goal conditions completed a self-report questionnaire following Trial 10. This questionnaire was comprised of items assessing spontaneous goal setting, the frequency of various types of thoughts during the final set of trials (Trials 8 - 10), and items pertaining to general perceptions of the ATC task. The occurrence of various types of thoughts during the final three trials of ATC performance was assessed using a modification of Sarason's Cognitive Interference Questionnaire (CIQ) (Sarason, 1978; Sarason, Sarason, Keefe, Hayes, & Shearin, 1986). The CIQ is designed to assess the frequency of intruding thoughts during task performance and requires subjects to indicate, using a 5-point Likert rating scale (1 = Never; 5 = Very often), how frequently thoughts described in each statement occurred to the subject while performing a just completed task. In our modified version, items were written to include thoughts about various aspects of the task. A subset of CIQ items and new items assessing various on-task thoughts were administered using an 8-point Likert rating scale (1 = Never; 8 = Constantly). In particular, items assessed attention to task components, thoughts pertaining to performance evaluation, negative and positive self-reactions, and off-task thoughts.

Subjective task perceptions were also assessed to determine potential attitudinal differences among subjects as a consequence of the goal manipulation. Subjects completed four Likert rating-scale items assessing perceived task difficulty and task pressure.

Performance measures. Multiple measures of task performance were obtained at each trial, including number of planes landed (Landings), number of rule violations (Errors), cumulative performance score, mean reaction time to wind changes, and number of plane crashes. Two measures, landings and errors, were used in all analyses of performance. These two measures are displayed on the screen during the task and are combined to generate the cumulative performance score. These measures have the additional advantage over cumulative performance score of being ratio scale measures of performance. The landings and errors measures were relatively independent, though negatively correlated (average correlation between the two variables for any given trial was $r = -.208, p < .01$). Other task-based measures were also obtained. Number of rule call-ups by all subjects, and number of performance/goal feedback call-ups by subjects in the Early Goal were also recorded for each (goal-present) task trial.

Results

One major purpose of this experiment was to review the basic skill acquisition parameters of the ATC task, including an examination of ability/performance relations. In addition, the goal setting manipulation was implemented to evaluate the overall impact of goal setting in this complex task acquisition scenario. From the latter perspective, Experiment 1 was seen as exploratory.

Goal Manipulation Check. To examine the potential influence of ability on distal motivational mechanisms, one-way analyses of variance were conducted on predicted performance score, goal commitment and self-confidence in goal attainment among subjects in the Early goal condition. As expected, ability exerted a significant effect on subjects' predicted performance score ($F (1, 106) = 8.01, p < .01$)⁴. Subjects in the

⁴ Thirty-seven subjects (18 Low ability; 19 High ability) were designated as missing on this measure due to failure to understand instructions for how to enter predicted score on the computer. Unlike other measures requiring a 1 - 7 response, this question required subjects to enter their predicted score.

low ability group predicted attainment of a lower performance score ($\hat{\mu} = 1484.48$) than subjects in the high ability group ($\hat{\mu} = 1680.76$). Nonetheless, ability had no significant effect on commitment to attaining the assigned goal ($F < 1$) nor on self-confidence ratings for goal attainment ($F < 1$). Overall, Early Goal subjects reported a moderate commitment to goal attainment ($\hat{\mu} = 4.57$). However, subjects generally reported relatively low confidence in their capability for goal attainment ($\hat{\mu} = 6.71$ -- higher scores reflect lower self-confidence ratings) and predicted their performance score to be substantially below the 1900-point goal assignment ($\hat{\mu} = 1604.43$ points). Consistent with prior findings (e.g., Wood & Bandura, 1988; Locke, Frederick, Lee, & Bobko, 1984), the correlation between self-confidence ratings and predicted score was significant ($r = -.54, p < .001$). Both predicted score and self-confidence in goal attainment were also significantly correlated with Trial 1 performance ($r = .27, p < .01, r = -.15, p < .05$ respectively). This pattern of findings indicates that low expectations about capability for goal attainment were more closely associated with Trial 1 performance than with intellectual abilities, as measured by the ASVAB.

The influence of ability on self-regulatory cognitive activities during the goal trials was examined with a set of one-way ANOVAs on measures taken during and following the goal trials. As expected, no significant effects for ability were obtained on reported attention to the goal ($F < 1$), extent of performance-monitoring ($F < 1$), or number of goal/performance feedback call-ups during the goal trials ($F < 1$). Early Goal subjects reported thinking about the assigned goal "almost all the time" ($\hat{\mu} = 21.1$). However, subjects only requested a mean of 4.64 goal feedback call-ups during the three goal trials (although there were 27 possibilities to call-up the feedback). This latter finding raises the possibility that the goal manipulation may have been less effective in stimulating self-regulatory processing during the goal trials than desirable.

Performance: Behavioral Measures -- Ability/performance results. One major set of hypotheses about task performance (Landings) pertained to initial ability/performance correlations, and changes in these correlations during skill acquisition. Given that the task was complex and novel (but one that involved consistent information processing demands), the expectation was that performance would be initially determined by general intellectual abilities. Furthermore, these correlations were expected to attenuate as practice continued. In contrast, correlations between perceptual speed measures were predicted to increase in association with performance, then decrease with later practice. (For a complete review of the theory of cognitive determinants of skill acquisition, see Ackerman, in press). To assess ability/performance relations across task trials, ability factors were derived from the ASVAB. The Dwyer Extension procedure (Dwyer, 1937) was used to obtain correlations between ability factors and task performance at each task trial. Correlations between the two key abilities (a General intellectual ability factor and a Perceptual Speed ability factor) are presented in Figure 7 - Panels A and B, respectively (these correlations were derived separately for the No Goal and Early Goal conditions).

Insert Figure 7 - Panels A,B about here

As can be seen from the figure, the data were generally consistent with the predictions. Initial performance was moderately associated with the General ability factor ($r = .45$ and $.49$, for No Goal and Early Goal conditions, respectively), and later performance showed decreasing correlations with the General ability. Also, at least in the No Goal condition, Perceptual Speed showed increasing, then decreasing correlations with performance (that are associated with transitions through the skill

acquisition phases).

The first indication of ability - motivation interactions is revealed by the differences between the pattern of ability/performance correlations for the No Goal and Early Goal groups. At Trial 1 (pre-treatment), the general ability/performance correlations are equivalent for the two groups. However, when the goal manipulation is implemented, the correlation between general ability and performance (in the Early Goal group) drops to a greater degree than occurs in the control group ($r = .45$ to $.42$ in No Goal, $r = .49$ to $.31$ in Early Goal; a test for the significance of the difference between Trial 1 and Trial 2 correlations for the Early Goal group is significant, $t(146) = 3.95, p < .001$). This decline in association continues through the remaining task trials, *even after the goal is removed (i.e., after Trial 4)*. That is, the goal setting intervention lead to a reduced dependence of task performance on general intelligence; a prediction exactly opposite the one posed by Vroom (1964), who maintained that performance is a multiplicative function of ability and motivation.

In addition, although less dramatic, there is an attenuated increase in Perceptual Speed ability/performance correlations in the Early Goal condition (again, the correlations were equivalent at Trial 1). No peak is seen in the Early Goal correlations (at least in the amount of practice given), suggesting that the subjects did *not* reach the later stages of skill acquisition. Taken together, the two ability/performance correlation patterns indicate that the goal manipulation reduced the role of cognitive/intellectual abilities in determining individual differences in performance.

Means and ANOVA results. Results of separate 2 X 2 (Goal X Ability) ANOVAs on landings and errors on Trial 1, prior to the goal assignment, indicated the expected significant main effects for ability on landings ($F(1, 309) = 64.05, p < .001$), but no significant effects for errors. Low ability subjects landed substantially fewer planes than high ability subjects. No significant effects were obtained for the Goal factor. Given the power associated with this sample size, such a result (along with random assignment to treatment), provides confidence in a lack of pre-treatment differences between these groups.

Contrasting hypotheses were possible for the goal manipulation, given little *a priori* knowledge about the task information-processing demands. If the task were pitched at an easy level (i.e., few resource demands), subjects were expected to benefit from goal setting (though low ability subjects would be expected to benefit the most). If the task were pitched at a too difficult level, subjects were expected to show deficits associated with the competing resource demands of the task and self-regulation (with low ability subjects expected to show the largest deficits). To test these possibilities, 2 Goal x 2 Ability x 9 Trial (Trial 2 - 10) repeated measure ANOVAs were conducted separately on landings and errors.

With respect to error scores, significant main effects were obtained for ability ($F(1, 2464) = 4.77, p < .05$) and trial ($F(1, 2464) = 19.12, p < .0001$). High ability subjects made fewer errors ($\hat{\mu}_{HI} = 9.32$) than low ability subjects ($\hat{\mu}_{LO} = 10.82$). In addition, all subjects made significantly fewer errors with practice ($\hat{\mu}_{T1} = 12.68$; $\hat{\mu}_{T10} = 8.97$). No other significant main or interaction effects were obtained for errors.

For landings, significant main effects were obtained for ability ($F(1, 308) = 19.03, p < .0001$; $\hat{\mu}_{HI} = 34.07, \hat{\mu}_{LO} = 30.19$) and Trial ($F(8, 2464) = 593.80, p < .0001$), as well as a significant Ability X Trial interaction effect ($F(8, 2464) = 6.67, p < .0001$). The Ability X Trial interaction indicates that low and high ability subjects converged in

performance during task practice (low ability subjects improved more over trials). Among low ability subjects, mean number of landings increased from 16.79 to 36.59 (Trial 2 to Trial 10). Among high ability subjects, mean number of landings increased from 23.53 to 39.97. The Ability x Trial interaction was consistent with ability/performance theory expectations, and with the ability/performance correlations reported above (see also Ackerman, 1987, in press).

Across the nine task trials, results obtained in both landing and error score analyses indicated no significant Goal effect ($F < 1$) or Goal X Ability interaction effects ($F(8, 2464) = 1.08, p > .05$). In comparison to the hypothesized results, we can conclude that the task was neither pitched too difficult nor too easy for the subject population under investigation.

However, since attentional demands imposed by the task were expected to decline over practice, and should have declined more quickly for high ability subjects (see Figure 7 above), we expected a lagged, or emergent effect of the goal manipulation on performance at later trials. That is, any benefit from the goal will be expected to accrue first to the high ability subjects. To test this notion, we conducted a *post hoc* 2 X 2 X 3 (Goal X Ability X Trial) ANOVA on landings obtained in the final set of three trials (Trials 8 - 10). The results of this analysis did indeed indicate a Trial X Goal X Ability interaction ($F(2, 616) = 5.99, p < .01$). This finding strengthens the notion that the goal assignment did exert a subtle, emergent effect on performance.

Examination of the interaction, shown in Figure 8, indicates that at Trial 8 Early Goal subjects performed about the same as the No Goal subjects. However, by Trial 10, subjects in the high ability, Early Goal group demonstrated increased performance in comparison to the No Goal group, while subjects in the low ability, Early Goal group continued to perform at a level equivalent to the low ability, No Goal group. This finding strengthens the notion that the goal assignment exerted a emergent effect on performance during skill acquisition.

Insert Figure 8 about here

Consistent with our proposed model, the late performance improvement among high ability, Early Goal subjects appears related to the declining attentional demands imposed by the task. The lack of performance improvement during later trials among low ability, Early Goal subjects is consistent with the notion of resource constraints associated with intellectual ability. For the low ability subjects, the slower decline of resource demands did not appear to enable these subjects to take advantage of self-regulatory activity.

Attentional Measures. Results obtained on 2 X 2 (Goal X Ability) ANOVAs of attentional measures taken following Trial 10 are shown in Table 1. Significant main effects for ability were obtained on four of the nine variables. Low ability subjects reported more spontaneous goal setting, spending more time thinking about their performance compared to others, and reported having more frequent negative self-reactive thoughts than high ability subjects. Early Goal subjects also reported checking their performance scores during the final task trials less frequently than No Goal subjects. This pattern of findings is consistent with the performance results that indicate a relatively more powerful effect of individual differences in ability relative to the motivational intervention. The less frequent performance checking by Early Goal subjects (compared to No Goal subjects) during the final set of task trials supports the

inference that the initial goal assignment had an emergent effect on later attentional allocation policies. This explanation implies that Early Goal subjects allocated few resources to self-regulatory activities because of high task demands on available attention and/or low self-confidence in goal attainability. Interestingly, high ability subjects also reported the ATC task to be more difficult than low ability subjects.

Insert Table 1 about here

Discussion

Results obtained in this experiment show that ability exerts a strong influence on early performance in complex skill acquisition. Consistent with the proposed model, the influence of general ability on performance attenuates as attentional demands of the task decline with practice. The pattern of declining general ability-performance correlations is consistent with previous findings in the literature (e.g., see Ackerman, 1987). In our ATC task, this pattern is further reflected by greater performance improvement of low ability subjects with practice, compared to high ability subjects (i.e., the Ability X Trial interaction).

The pattern of ability-performance correlations obtained in the Early Goal condition provides some evidence of a demand on cognitive resources associated with the goal assignment. Nonetheless, goal assignments made during the initial stage of skill acquisition appeared to exert no global mean effects on performance. Further examination of manipulation effects on self-regulatory activities may help explain this finding. During the early stage of skill acquisition, attentional demands imposed by the task were high and mean Trial 1 landing performance was generally quite low ($\bar{u} = 9.08$). Given the high resource demands of the task and the strong, positive correlation between Trial 1 performance and self-confidence ratings in capability for goal attainment, subjects may have opted to allocate fewer resources to self-regulatory activity in favor of greater allocations to on-task performance. The relatively low level of "F10" goal/performance call-ups during the goal trials supports this explanation and suggests that the goal manipulation stimulated only minimal self-regulatory activity. Failure to trigger substantial self-regulatory activity among Early Goal subjects, in turn, would explain the absence of motivational effects on the performance measure.

Finally, the main effect of ability on self-report measures of attentional activity during the last three trials is particularly interesting. Low ability subjects reported more frequent thoughts about performance compared to others and more frequent negative self-reactions during the final three task trials compared to high ability subjects. The presence of a main effect for ability on landings precludes determination of whether the more frequent self-evaluative thoughts and lower level of performance checking were a partial cause or consequence of performance. In either case, however, our model indicates that allocation of attentional resources to off-task activities will impair skill acquisition and task performance.

VI. SERIES 1 -- EXPERIMENT 2

The first experiment provided the baseline data for the ability/performance relations, along with some indications of the nature of goal setting influences in this complex skill acquisition task. The next step was to further examine the facilitative effects of a goal setting manipulation in the context of skill acquisition.

Two features of the integrated model were investigated in this study. First, the proposed model indicates that the *products* of self-regulatory processing may aid learning, depending upon the extent to which self-regulation strategies ultimately increase on-task attentional effort (Bandura, 1986; F. Kanfer & Hagerman, 1987; Kuhl, 1986). To attain these benefits, however, persons must have sufficient available cognitive resources. Second, the model predicts a reduction in attentional resource demands with practice as persons develop a declarative representation of the task procedures. As task resource demands are reduced, additional cognitive resources become available for self-regulation. Although motivational interventions triggering self-regulatory activities demand cognitive resources, such resources are not required for adequate task performance, *once the cognitive phase of skill acquisition is completed*. Thus, an imposed goal is not expected to shift critical resources away from task performance. Furthermore, since there are spare resources available, the increased task effort product of self-regulation can be reallocated back into on-task activities. Thus, we predicted that self-regulatory activities engaged during the intermediate phase of skill acquisition would *enhance* task performance.

Method

Subjects

In this experiment, 144 U.S. Air Force trainees (all males) were run in the Late Goal assignment condition. Subjects were tested in "flights," as described in Experiment 1. (Prior to data analysis, data from two subjects were discarded for failure to follow task instructions.) As in Experiment 1, because a few subjects had incomplete data (e.g., computer failure, sickness), the degrees of freedom differ by as much as 2 or 3 *df* on some analyses.) The final sample contained 142 subjects.

Procedure

The procedure used in this experiment was identical to that in Experiment 1, except the motivational manipulation was introduced at a *later* stage of practice (i.e., at Trial 5). Subjects in the "Late Goal" condition received "do your best" instructions for task Trials 1 - 4. Prior to Trial 5, Late Goal subjects received their first goal assignment. These subjects were assigned a cumulative performance score goal of 2200 points (per trial) for Trials 5, 6, and 7. The 2200-point goal was selected on the basis of prior research indicating that this score represented a difficult performance goal (approximately 90th percentile) for Trials 5, 6, and 7. Late Goal subjects completed questionnaires prior to and following the goal trials. As in Experiment 1, subjects were provided the opportunity to periodically check their performance with respect to the goal during the three assigned goal trials, using the "F10" key. Following Trial 7, Late Goal subjects were instructed to "do your best" for the remaining three task trials.

Dependent measures. Ability, performance, and self-report measures were identical to those used in the previous experiment.

Results

Manipulation Checks

Goal manipulations. Again, one-way ANOVAs on self-report measures of distal motivation were conducted to assess the impact of ability on these variables. A significant effect for ability was obtained on subjects' predicted performance scores (F

(1, 123) = 5.11, $p < .03$)⁵. As occurred in Experiment 1, both low and high ability subjects predicted attainment of performance scores below the goal assignment ($\hat{\mu}_{\text{Low}} = 1854.43$; $\hat{\mu}_{\text{High}} = 2012.97$). Nonetheless, ability had no significant effect on goal commitment ($F < 1$) or self-confidence ratings for goal attainment ($F < 1$).

To compare the relative influence of the Early Goal and Late Goal assignments, a series of 2 X 2 (Ability X Goal) ANOVAs were also conducted. No significant differences were obtained between level of goal commitment among Early and Late goal subjects. However, subjects in the Late Goal assignment condition reported significantly higher self-confidence in capability for goal attainment than Early Goal subjects ($F (1, 290) = 16.38, p < .001$; $\hat{\mu}_{\text{Early}} = 6.71, \hat{\mu}_{\text{Late}} = 5.33$). Corresponding to the correlational results obtained in Experiment 1, self-confidence ratings among Late Goal subjects were not significantly correlated with intellectual ability ($r = -.04$) but were significantly correlated with predicted performance score ($r = -.59, p < .001$) and prior trial performance ($r = .34, p < .001$). (In this case, Trial 4 was the preceding trial.) The similarity between correlational patterns in Early Goal and Late Goal conditions suggests that the higher self-confidence ratings of Late Goal subjects may be associated with self-observations of improvement over trials.

Late Goal subjects also reported significantly more frequent self-regulatory activity during the goal trials compared to Early Goal subjects. Late Goal subjects reported a higher frequency of performance monitoring ($F (1, 289) = 10.64, p < .001$; $\hat{\mu}_{\text{Early}} = 6.86, \hat{\mu}_{\text{Late}} = 8.20$), compared to Early Goal subjects. Furthermore, Early Goal subjects used the "F10" key call-ups significantly fewer times than did Late Goal subjects ($F (1, 290) = 11.90, p < .001$; $\hat{\mu}_{\text{Early}} = 4.63, \hat{\mu}_{\text{Late}} = 7.39$). These findings support the inference that Early Goal assignment in Experiment 1 resulted in less self-regulatory activity compared to Late Goal assignment.

Performance: Behavioral Measures

Tests of the Ability X Motivation interactions were conducted by comparing Trial 5 - 10 performance of Late Goal subjects to corresponding trial performance of No Goal subjects in Experiment 1. A 2 X 2 X 6 (Goal X Ability X Task Trial) repeated measure ANOVA was conducted on landing and errors. The Error score ANOVA indicated a significant main effect for Trial ($F (5, 1515) = 6.08, p < .0001$); all subjects made fewer errors with practice. No other significant effects or interactions were obtained on this measure.

Results obtained in the ANOVA of landings demonstrate a significant main effect for Ability ($F (1, 303) = 14.38, p < .001$) and Trial ($F (5, 1515) = 118.70, p < .0001$). High ability subjects landed more planes than low ability subjects across all trials, although both high and low ability subjects improved with practice. Examination of the ability - performance correlations obtained in the Late Goal condition provides additional evidence for these effects. As shown in Figure 9 - Panels A and B, the pattern of ability-performance correlations across trials among Late Goal subjects is characterized by a gradual decline across task trials, essentially equivalent to the No Goal condition. The major difference between the No Goal and Late Goal curves pertained to the Perceptual Speed/performance correlations. Similar to the Early Goal condition, the Late Goal data show a slower rise in correlations (after Trial 4 - when

⁵ Thirteen subjects (10 Low ability, 3 High ability) were designated as missing due to failure to understand instructions for entering their predicted performance scores.

the goal is implemented), again indicating a disruption of the normal skill acquisition sequence.

Insert Figure 9 - Panels A and B about here

In addition to significant main effects, a significant Goal X Trial interaction effect ($F(5, 1515) = 3.42, p < .01$) was also obtained on landing scores. As shown graphically in Figure 10, subjects in the Late Goal condition showed greater performance improvement over trials compared to the No Goal condition. This interaction effect provides support for the hypothesized beneficial effects of motivation when implemented during an intermediate phase of skill acquisition. These data support the hypothesis that the benefits of motivational manipulations occur as the resource demands of the task decline during skill acquisition (in comparison with Experiment 1). No significant Goal X Ability interaction was obtained, suggesting that the task was not yet resource-insensitive for high ability subjects. Taken together, these findings indicate that, during an intermediate stage of skill acquisition, low and high ability subjects derive *parallel* benefits from the motivation manipulation.

Insert Figure 10 about here

Attentional Measures

Results obtained on 2 X 2 (Goal X Ability) ANOVAs of attentional measures taken following Trial 10 are displayed in Table 2. Consistent with findings obtained in Experiment 1, low ability subjects reported significantly more spontaneous goal setting than high ability subjects ($\hat{\mu}_{Low} = 7.23$; $\hat{\mu}_{High} = 8.05$). However, subjects in the Late Goal condition reported significantly less spontaneous goal setting than subjects in the No Goal condition ($\hat{\mu}_{Late Goal} = 8.12$; $\hat{\mu}_{No Goal} = 7.19$). Subjects in the Late Goal condition also reported less attention to their performance score compared to No Goal subjects ($\hat{\mu}_{Late} = 3.83$; $\hat{\mu}_{No} = 5.11$).

Insert Table 2 about here

A significant Ability X Goal interaction was obtained on frequency of thoughts about normative performance. In this crossover interaction, low ability subjects reported more comparison thoughts than high ability subjects in the No Goal conditions ($\hat{\mu}_{No Goal, Low} = 10.33$; $\hat{\mu}_{No Goal, Hi} = 8.86$), while the reverse pattern was obtained for the Late Goal condition ($\hat{\mu}_{Late Goal, Low} = 8.76$; $\hat{\mu}_{Late Goal, Hi} = 9.68$). No significant main or interaction effects were obtained on positive or negative self-reactions during task performance, perceived task difficulty, or perceived task pressure.

Discussion

The results obtained in Experiment 2 demonstrate that a motivational intervention during the intermediate stage of skill acquisition (i.e., when ability/attentional task demands are partly attenuated), enhanced task performance. The imposition of a Late Goal assignment was also associated with higher reported levels of self-regulatory activity during the goal trials. The gradual decline of general intellectual ability -

performance correlations across trials suggests that activation of self-regulatory activity did not drain resources from task performance but in fact may have redirected attentional effort toward the task. This result is consistent with the delayed increases in Perceptual Speed - performance correlations (see Figure 9). The failure to obtain an Ability X Goal interaction effect on performance indicates that high ability subjects continued to benefit from on-task allocations of effort, suggesting that high ability subjects continued to operate within the resource-limited portion of the performance-resource function.

As shown in the comparison of Early Goal and Late Goal groups on measures of reported self-regulatory activity, Early Goal subjects engaged in less self-regulatory activity than Late Goal subjects. Two explanations for this finding may be proposed. First, an unspecified cognitive contingency mechanism might exist that controls the operation of self-regulatory activities depending upon the attentional demands of the task. For example, when task demands are high, this mechanism would automatically limit the allocation of attention, but when task demands are reduced, resource allocations to self-regulation would be placed under volitional control. Such a mechanism might be associated with so-called learning abilities.

An alternative explanation is that the differential self-observations of performance made by subjects in the Early and Late Goal conditions affected their willingness to engage in goal-directed self-regulatory activity. Lower confidence ratings in goal attainment among Early Goal subjects may have been due to observation of one trial of relatively poor performance. In contrast, Late Goal subjects observed improvement in their performance over the four trials preceding the goal assignment.

A test of these explanations with respect to the demands and consequences of self-regulatory activities on task performance requires creating a situation in which subjects' observations of their past performance leads to similar perceptions of confidence in goal attainment despite differences in the development of skills. If the cognitive, ability-based mechanism explanation is correct, then the provision of a goal assignment during the declarative phase of skill acquisition (when task demands are high) should markedly hinder the performance of low ability persons but not affect the performance of high ability persons (compared to a No Goal control condition). When attentional demands are reduced, however, the provision of a goal assignment during the intermediate phase of skill acquisition should enhance the performance of both groups as predicted by the model.

In contrast, if the self-confidence explanation is correct, then the provision of a goal assignment during the declarative phase of skill acquisition should exert the effects hypothesized by the integrated model. That is, high ability persons should also demonstrate lower performance compared to a No Goal control condition. Goal assignments during the intermediate phase of skill acquisition would be expected to enhance task performance as predicted by the model. Experiment 3 was designed to further explore these hypotheses, by an explicit manipulation of the task information-processing demands in a part-task training paradigm.

VII. SERIES II - EXPERIMENT 3

Experiments 1 and 2 provided data that addressed several issues outlined in the proposed motivation/ability/information processing framework. The findings obtained in these two experiments are consistent with the changing ability/performance correlations expected within the proposed framework. Furthermore, the results of these experiments provide tentative support for the proposition that the impact of

motivational interventions (e.g., goal setting) on performance depends on the dynamic changes in attention/information-processing demands of the task during skill acquisition.

The third, and final, experiment confronts the hypothesized joint effects of ability differences, self-regulatory activities and attentional/information processing demands within an explicit experimental paradigm. That is, we alter the information-processing demands of the task with a set of two different part-task training procedures, denoted "declarative" and "procedural." One part-task procedure (declarative knowledge training) was implemented in order to reduce the attentional demands of the full ATC task. Thus, when the task attention demands are reduced, goal setting (that triggers self-regulatory activities), is expected to lead to performance improvements. The second part-task procedure (procedural knowledge training), was also structured to facilitate full-task performance, but to do so without reducing cognitive/declarative resource demands of the full task. Goal setting that triggers self-regulatory activities, when the subjects were under high resource load, is expected to result in a decrement in performance.

In keeping with the concepts of the three phases of skill acquisition, the purpose of the "Declarative" part-task training paradigm was to allow subjects to form a declarative knowledge foundation for performing the ATC task prior to full-task engagement. This declarative knowledge training was designed so that subjects begin the full task at a point close to where the resource demands for performance begin to markedly diminish.

The "Procedural" knowledge part-task training paradigm was also structured to facilitate full task performance. However, procedural knowledge training only focused on development of the motor sequence skills that facilitate performance in the full task. As such, there is positive transfer from training to full-task transfer, but the cognitive/declarative attentional resource demands of the task have not been markedly reduced. Thus, subjects engaged in Procedural part-task training were expected to begin the full-task at a point where resource demands for performance remain high.

Given that both Declarative and Procedural part-task training paradigms involve repetitive trials in which persons improve with practice, we expected subjects in both part-task conditions to demonstrate similar, high levels of self-confidence in goal attainment prior to starting the first full-task ATC trial.

Three sets of general hypotheses were drawn from the proposed model, and from the nature of these part-task training procedures:

- (1) With Declarative knowledge part-task training, goal setting will facilitate skill acquisition (with greater facilitation as the skills are acquired -- i.e., an emergent effect).
- (2) With Procedural knowledge part-task training, goal setting will impair skill acquisition.
- (3) Given that low ability subjects are most likely to perform in a more resource-limited area of the performance-resource function, benefits and impediments from goal setting will have greater impact on the performance of low-ability subjects than on high-ability subjects.

Method

Subjects

Participants in this study were 568 U.S. Air Force recruits (166 females). Subjects were tested in "flights," as described in Experiment 1. (Prior to data analysis, data from a few subjects were discarded, some for a lack of ability testing records (3), and others for failure to follow task instructions (13). Finally, because a few subjects had incomplete data (e.g., computer failure, sickness), the degrees of freedom differ by as much as 2 or 3 *df* on some analyses.) The final sample size was 552 subjects.

Procedure

As in Experiments 1 and 2, all subjects received via computer, an introduction to the session, and instructions for performing the ATC task at the start of the experimental session. Following completion of the standard instructions, subjects were then assigned by "flight" to either a Declarative ($N = 278$) or Procedural ($N = 274$) part-task training condition.

Part-Task Training Manipulations

The part-task training manipulations were designed to result in different ATC task performance-resource functions by providing subjects with two types of part-task training prior to engaging in the full ATC task. Subjects performed 210 trials (over about a 40 minute period) in either a Declarative or Procedural part-task training condition.

Declarative part-task training. In this condition, subjects were required to *learn the rules* of the ATC task. Subjects were told that the purpose of the part-task training procedure was to help prepare them for performing the full ATC task. Subjects were instructed to respond to the question in each scenario as quickly as possible, while maintaining an accuracy level of about 90% correct over each trial block.

Subjects were shown a series of static task scenarios. In each scenario, an ATC rule was shown and a question was asked that related to the proper operation of the task with respect to the given rule. An example scenario presented to subjects is displayed in Figure 11. In this scenario, the display indicates an attempt to land a 747 plane from the hold pattern onto a short runway. Rule 4 (which governs the plane type - runway type matching conditions) is also displayed on the screen along with an inquiry ("Is a carriage return a legal move [for this situation]?""). Subject were required to indicate the correct answer to the question by pressing keys designated as "Yes" or "No." Immediately following the response, a feedback message was displayed for 1.5 sec. before a new scenario was presented. Feedback following each response indicated: (1) the correctness of the response, (2) the cumulative accuracy of responses within the trial block, and (3) the cumulative mean reaction time of correct responses within the trial block. After each trial block, subjects received information on the average accuracy and reaction time of correct responses across trial blocks.

Insert Figure 11 about here

Scenarios were divided into 7 trial blocks, consisting of 30 scenarios per block. All six ATC rules were covered in a comprehensive manner across trial blocks, although each trial only queried about a single rule. The simplest rules were included in early trial blocks, and complex rules were given in later trial blocks.

Procedural part-task training. In this condition, subjects received practice in learning the keyboard response procedures of the task. Subjects were shown a series of dynamic task scenarios (presented in real time) and subjects were instructed to complete the key sequence that was displayed on the screen. An example of a trial task scenario is shown in Figure 12.

Insert Figure 12 about here

Each trial/key sequence scenario represented logical moves (or series of moves) that would be followed by a skilled ATC task performer. As illustrated in the figure, a subject could be shown a scenario with a plane in Position "2e" of the hold pattern. The instructions tell the subject to perform the specific key sequence that would select the plane, move it from Level 2 to Level 1, and then from Level 1 to an appropriate runway. Subjects were instructed to press the keys rapidly, but also to note the results of the key-presses which were displayed on the screen as the keys were pressed. If an incorrect key was pressed, the trial ended, and the subject was shown and "Error" message. Otherwise, after completion of each correct key sequence, subjects were shown a "Correct" message. In addition, accuracy information was presented at the end of each of 30 trials. Subjects received 7 blocks of trials. The length and complexity of key sequences increased within and across trial blocks.

Goal Manipulations

Following completion of part-task training, all subjects performed six, 10-minute trials of the full ATC task. Prior to beginning the full ATC task, half the subjects in each part-task training condition were randomly assigned to a No Goal condition. Remaining subjects were assigned to the Goal conditions. Thus, there were four between-subject conditions in this experiment:

- (1) Declarative - No Goal
- (2) Declarative - Goal
- (3) Procedural - No Goal
- (4) Procedural - Goal

Subjects in the Goal conditions were assigned a specific and difficult performance goal of 2200 points for each of the first three full task trials (Trials 1 - 3). The goal was identical to that assigned in Experiment 2. Also, as in Experiment 1 and 2, when the goal was activated, subjects were also provided with the opportunity to check their goal progress with the "F10" key. Subjects in the No Goal conditions were instructed to "do your best" on each trial. For trials 4 - 6, all subjects were instructed to "do your best."

Dependent Measures

Ability, performance, and self-report measures described previously were again used in this experiment. Distal motivational processes and self-regulatory activity among subjects in the Goal conditions was assessed prior to beginning the first full ATC task trial and immediately following Trial 3.

Results

Manipulation Checks

Part-task training manipulations. To assess the extent to which the Declarative part-task training procedure facilitated declarative knowledge representation, a 2 X 2 X 2 (Training X Goal X Ability) ANOVA was conducted on composite scores from the Rules/Knowledge Test. The scoring scheme used for coding free-form responses to the Rules/Knowledge test was to assign 1-point for correct description of each rule (or sub-component of a rule). A composite Rules/Knowledge test score was obtained for each subject by summing the points earned across all rules. Maximum score possible was 14 points.

ANOVA results support the contention that Declarative part-task training improved declarative knowledge of the rules. Although the subjects did not yet have complete knowledge of all the rules, subjects in the Declarative condition remembered an average of one rule more than subjects in the Procedural condition ($F(1, 548) = 17.10, p < .001; \hat{\mu}_{Dec} = 5.74, \hat{\mu}_{Proc} = 4.78$). Further, the mean score obtained in the Procedural training condition is quite similar to the overall mean score obtained by No Goal subjects in Experiment 1 ($\hat{\mu} = 4.66$), suggesting that the Procedural training condition did not substantially affect declarative task knowledge in a manner different from task performance only. In accord with the notion of ability as an important determinant of learning, a significant main effect for ability ($F(1, 548) = 79.34, p < .001, \hat{\mu}_{Hi} = 5.74, \hat{\mu}_{Lo} = 4.78$) was also obtained, with high ability subjects remembering approximately two rules more than low ability subjects ($\hat{\mu}_{Hi} = 6.18, \hat{\mu}_{Lo} = 4.33$). Of further note is the significant main effect for Goal ($F(1, 548) = 6.11, p < .05$). Subjects in the Goal conditions remembered an average of 0.5 fewer rules than subjects in the No Goal conditions ($\hat{\mu}_{Goal} = 5.04; \hat{\mu}_{No Goal} = 5.49$).

Goal manipulations. A fundamental issue in the experiment concerned the similarity among groups in initial self-confidence ratings of capability to attain the assigned goal (i.e., for Declarative - Goal and Procedural - Goal conditions). Results obtained in a 2 X 2 (Training X Ability) ANOVA on this measure indicate no significant main or interaction effects. Overall, subjects in Experiment 3 reported a relatively high level of self-confidence ($\hat{\mu} = 5.61$), similar to the level of the Late Goal subjects in Experiment 2 ($\hat{\mu} = 5.33$). This finding permits testing of the cognitive, ability explanation and lends support for the notion that group differences in self-confidence ratings in Experiments 1 and 2 were related to systematic differences in self-observation of prior ATC task performance.

A similar 2 X 2 (Training X Ability) ANOVA on goal commitment scores indicated no significant main or interaction effects. Findings obtained on predicted performance score, however, reveal a significant main effect for Ability ($F(1, 225) = 13.49, p < .001$)⁶. High ability subjects expected to attain higher performance scores than low ability subjects ($\hat{\mu}_{Hi} = 1780; \hat{\mu}_{Lo} = 1298$).

Analyses conducted on measures of self-regulatory activities during the assigned goal trials provide partial support for the cognitive, ability explanation. A significant main effect for ability was obtained for self-reported attention to performance ($F(1, 274) = 4.75, p < .05$), but no significant ability effect was obtained for attention to the goal. High ability subjects reported less frequent performance monitoring ($\hat{\mu}_{Hi} = 6.63; \hat{\mu}_{Lo} = 7.47$) than low ability subjects. Given the absence of an ability effect on self-

⁶ Forty-six subjects (31 Low ability, 15 High ability) were designated as missing on this measure due to failure to understand instructions for responding to this question.

confidence ratings, these findings suggest that variability in specific self-regulatory activities is associated with intellectual abilities.

Performance: Behavioral Measures

Ability/Performance Data. As shown in the ability - performance correlation patterns displayed in Figure 13, correlations between General ability and performance start off moderate and decline with practice across all four conditions (initial average $r = .48$, final average $r = .26$).

Insert Figure 13 about here

Particularly noteworthy, though, are the differences between the No Goal/Goal patterns for Declarative and Procedural conditions. While the *initial* correlations between General ability and performance are essentially equivalent for the Declarative - No Goal and Goal groups, they are markedly larger in the Procedural - No Goal group than the Procedural - Goal group, though only for the first two trials. In comparison to the results from Experiments 1 and 2, the lower General ability - performance correlations in the Procedural - Goal condition mirrors those in the Early Goal condition. The similarity of No Goal/Goal curves in the Declarative conditions mirrors the equivalent curves found in the No Goal/Late Goal comparison. Such findings support our earlier inferences about the conditions that reflect intensive resource demands associated with early phases of skill acquisition (the Procedural and Early Goal conditions), and similarly reflect reduced resource demands associated with later phases of skill acquisition (the Declarative and Late Goal conditions).

Although there were only 6 trials of full ATC task practice, there is a general trend for Perceptual Speed/performance correlations to follow the expected pattern during skill acquisition. That is, correlations between Perceptual Speed and performance start off low at Trial 1 (average $r = .04$) and increase through the last full-task trial (Trial 6 -- average $r = .19$). The contrast between the No-Goal condition of the Declarative task and the Declarative - Goal condition is also consistent with the findings from Experiment 2. That is, the Goal condition shows a smaller initial correlation between Perceptual Speed ability and performance, and a steeper slope of increase over task trials. These data are consistent with inference (made earlier) that the Goal condition leads to a delay in knowledge compilation (that would be associated with a greater reliance on Phase 1 information processing during the goal trials). The patterns of Perceptual Speed - performance correlations for the two Procedural conditions do not address this issue in any definitive fashion since it was quite possible that some proceduralization of skills took place during the part-task training (and thus, prior to the full ATC task trials).

Landings -- Means and ANOVA results. A summary of the $2 \times 2 \times 2 \times 6$ (Training \times Goal \times Ability \times Trial) ANOVA on landings is provided in Table 3. As shown, a number of significant main and higher-order interaction effects were present. To clarify these effects in the context of the predictions, we will concentrate on these results with respect to Trial 1 of the full ATC task, Trial 6, and performance effects across the entire set of trials.

Insert Table 3 about here

Trial 1. The heaviest demands on the cognitive information processing system occur when subjects first encounter the full ATC task. (This fact is reflected in the ability/performance correlations discussed above). As shown in Figure 14, depicting the performance of Declarative (Panel A) and Procedural (Panel B) training groups across trials, initial performance differences in both part-task training conditions are clearly influenced by intellectual ability.

Insert Figure 14 about here

While no significant main effect was obtained for Training type, it is important to note that Trial 1 landings across both No Goal, part-task training conditions was significantly superior to Trial 1 performance in the No Goal condition run in Experiment 1 ($t(446) = 4.99, p < .001$; $\hat{\mu}_{\text{No Goal,Dec\&Proc}} = 12.02$; $\hat{\mu}_{\text{No Goal}} = 8.48$). That is, part-task training raised performance an average of 42% above novice performance obtained in the No Goal (no part-task training), control condition. Error rates did not significantly differ across these conditions ($\hat{\mu}_{\text{No Goal,Dec\&Proc}} = 11.75$; $\hat{\mu}_{\text{No Goal}} = 12.28$).

Under the high resource-load conditions, the self-regulatory demands of the Goal manipulation were hypothesized to create a classic dual-task scenario (i.e., in the Procedural - Goal condition). That is, subjects needed to share resources between the competing demands to perform the full ATC task *and* to attend to self-regulatory activities. An examination of this prediction was made with a *post hoc* ANOVA on Trial 1 performance. As expected, the Goal manipulation resulted in a general decrement in performance at this early stage of full-task practice ($F(1, 544) = 5.77, p < .02$). Based on the proposed model proposed above, the negative performance effects of the goal assignment were expected to be greater in the Procedural conditions. At this stage of practice, the Goal X Training interaction was indeed significant ($F(1, 544) = 5.33, p < .05$), though it was not a large effect.

Across trials. Across the six trials of full ATC task practice, the various influences of part-task training type and goal manipulations become more pronounced. The significant Goal X Training interaction effect in Table 3 supports the hypothesis of a differential effect of motivational processes contingent upon resource demands imposed by the task. Consistent with hypotheses derived from the model, the goal setting manipulation was beneficial in the Declarative condition (where cognitive resource demands were reduced) but detrimental in the Procedural condition (where cognitive resource demands remained high).

However, the crux of the investigation is revealed in the significant Training X Goal X Ability X Trial interaction. Although four-way interactions are often difficult to interpret, this result is also consistent with the proposed model and the hypotheses presented above. This interaction may be partially described by further examination of panels A and B in Figure 14. As illustrated in Panel A, the detrimental effect of the goal assignment in the Procedural condition was greater for low ability subjects than for high ability subjects. In contrast, as shown in Panel B, the beneficial effect of the goal assignment in the Declarative condition exerted a greater effect on low ability subjects than high ability subjects. When resource demands were high (Procedural condition), low ability subjects were *hurt more* than high ability subjects by the goal assignment, but when resource demands were reduced (Declarative condition) *low ability subjects benefitted more* from the goal assignment than high ability subjects.

Trial 6. The motivation/information-processing-demands interactions at the end of task training can be seen in Figure 15. Performance in the less resource-sensitive task condition (Declarative training), under the assigned Goal condition, was *superior* to performance in the No Goal condition. In contrast, performance in the resource-dependent (Procedural training) task condition, under the assigned Goal condition, was *inferior* to performance in the No Goal condition.

Insert Figure 15 about here

Additional ability interactions are seen at the end of the full ATC task trials in Figure 14. Low ability subjects in the Procedural Goal condition (see Panel A of Figure 14) appeared to approach a performance asymptote at a much lower level of performance than was found in the other conditions. In contrast, as illustrated in Panel B of Figure 14, low ability subjects in the Declarative Goal condition ultimately performed as well as high ability subjects in the Goal and No Goal condition; however, low ability subjects in the Declarative No Goal condition clearly demonstrate suboptimal asymptotic performance.

Errors. Results obtained in the ANOVA on error scores are presented in Table 4. The results of this analysis mirror the results of landings, with two notable exceptions. First, a significant main effect was obtained for training; subjects in the Declarative conditions made fewer errors than those in the Procedural conditions. As indicated by the Training X Trial interaction, this difference between training conditions attenuated with practice. At the beginning of the full ATC task, subjects in the Declarative conditions made an average of 28% fewer errors than subjects in the Procedural conditions ($\bar{\mu}_{Dec} = 9.97$, $\bar{\mu}_{Proc} = 13.81$). In Trial 6, subjects in the Declarative condition made only 2% fewer errors than subjects in the Procedural conditions ($\bar{\mu}_{Dec} = 10.42$, $\bar{\mu}_{Proc} = 10.66$).

Insert Table 4 about here

Second, a significant main effect for Goal was obtained on error scores. Subjects in the Goal conditions committed *more* errors than those in the No Goal conditions ($\bar{\mu}_{Goal} = 12.28$; $\bar{\mu}_{No\ Goal} = 10.77$), even though no omnibus Goal effect was found for the Landings variable.

Attentional Measures

Results obtained in 2 X 2 X 2 (Training X Goal X Ability) ANOVAs on subjective reports of cognitive activities during the final three trials of full ATC task performance and perceptions of task difficulty are shown in Table 5. The effects of the task manipulations and individual differences in ability on subjective responses are discussed in terms of three classes of cognitive activity: (1) spontaneous goal setting, (2) attentional focus, (3) perceived task difficulty; and, in terms of (4) affective self-reactions.

Insert Table 5 about here

Spontaneous goal setting. The significant main effect for ability on this measure is consistent with the fact that high ability subjects were less affected by the goal setting manipulation than low ability subjects. The significant Training X Goal interaction indicated that subjects in the Declarative goal condition set goals more often during Trials 4 - 6 than their No Goal counterparts. In contrast, subjects in the Procedural Goal condition set goals less often than their No Goal counterparts. These results suggest that subjects' adoption of goal setting procedures was influenced by their experience during the first three trials. When sufficient resources were available for goal setting (i.e. Declarative condition), subjects continued use of the goal setting procedure. When the demands caused by goal assignments drew resources away from task performance (i.e., Procedural condition), however, subjects appeared to respond by reducing use of the goal setting procedure in later trials.

In addition, the significant Ability X Goal interaction indicates that subsequent goal setting activity was also affected by the joint influence of goal assignments and resource availability. In the No Goal conditions, high and low ability subjects reported similar frequencies of spontaneous goal setting. In the Goal conditions, however, low ability subjects reported setting goals *more* frequently than high ability subjects. This finding is consistent with ability effects on self-report measures of self-regulatory activity during the assigned goal trials and suggests that high-ability subjects were more able to disregard non-optimal learning strategies than were low-ability subjects.

Attentional Focus. As shown in Table 5, a significant Training X Goal interaction effect was obtained for amount of attention directed to on-task activities. Consistent with the model and previously discussed performance findings, subjects in the Procedural - Goal condition reported devoting less attention to on-task elements than subjects in other conditions. In addition, Goal subjects reported significantly less performance checking during the final trials than No Goal subjects.

Examination of measures assessing non-task activities revealed an interesting pattern of results. Specifically, a significant main effect for ability was obtained on attention to performance compared to others, with high ability subjects reporting fewer of these thoughts than low ability persons. Furthermore, a significant Training X Goal interaction effect was obtained for attention to off-task activities and for thoughts about performance compared to others. Procedural Goal subjects reported allocating a *greater* amount of attention to off-task activities and normative standing than subjects in other conditions; a finding that is consistent with the results for on-task activities. Finally, a significant Ability X Training X Goal interaction obtained on the off-task variable indicated that low ability subjects in the Declarative, Goal condition reported less off-task activity than subjects in the other conditions.

Task perceptions. Results obtained on measures of perceived task difficulty and task pressure are consistent with the model and performance data. Significant main effects for Goal on both measures indicate that subjects in the Goal condition found the task to be more difficult and involve more pressure than No Goal subjects. In addition, low ability subjects perceived the task as *less* demanding than high ability subjects.

Affective reactions. As expected, positive and negative self-reactions were essentially uncorrelated ($r = -.02$). Analyses of both self-reaction variables indicated that low ability subjects reported more negative self-reactions and fewer positive self-reactions than high ability subjects. Imposition of the goal also increased frequency of negative self-reactions for both high and low ability subjects. However, examination of the significant Training X Goal interaction effect on negative self-reactions indicated

that Procedural - Goal subjects reported more frequent negative self-reactions than all other conditions. Thus, task and motivational manipulations in this study had a significant effect on negative self-reactions, but not positive self-reactions.

Discussion

The results obtained in Experiment 3 support the integrated model. In the Procedural training condition, goal assignments had a negative influence on performance, with a larger dysfunctional effect obtained for low-ability subjects than high ability subjects. In the Declarative training condition, Goal assignments had a positive influence on performance, with a larger beneficial effect on low ability subjects than high-ability subjects. Consistent with these performance results, Procedural - Goal subjects reported less attention to on-task activities, more attention to off-task activities and more frequent negative self-reactions. Subjects assigned a goal reported that the full ATC task was more difficult and pressured than subjects in the No Goal condition. Finally, ability exerted an effect on performance checking, perceptions of task pressure and frequency of reports of negative and positive self-reactions.

The absence of part-task training effects on self-confidence ratings among subjects in the Goal conditions reduces the likelihood that performance differences obtained were due to systematic differences in initial self-perceptions of performance capabilities. However, ability effects obtained on measures of self-regulatory activity during the assigned goal trials strengthen the possibility of ability-related differences in use of self-regulatory strategies.

VIII. GENERAL DISCUSSION

The theoretical framework and the three experiments presented here address the operation of dynamic interactions between conative and cognitive ability determinants of skill acquisition. The relatively large size of the samples, the range of talent on cognitive ability measures and likely heterogeneity in strength of achievement-related motives afforded by use of this field sample, the use of a complex and novel real-time task simulation task enabling assessment of longitudinal effects, and the similarity of findings across experiments add to the external validity and generalizability of the results obtained. Although it is encouraging that the pattern of findings provide initial support for our model, it is also the case that the findings raise a number of yet unresolved issues and have implications for future research in disparate motivation and cognitive ability research domains. The relevance of findings for each of these areas is discussed in turn.

Ability - Motivation Interactions

The results from our experiments support theory-based predictions of ability - motivation interactions during complex skill acquisition. However, only partial support is provided for Vroom's depiction of motivation - ability interactions. Our findings indicate that goal assignments provided during the declarative stage of skill acquisition may produce a decrement in performance among both low and high ability groups. In Experiment 3, the goal assignment resulted in an overall detrimental effect on performance with greater impairment demonstrated among low ability subjects than high ability subjects.

The ability - motivation interactions demonstrated in Experiment 3 were predicted from our theoretical framework, though such results run counter to the traditional

assumption that increasing motivation results in greater gain among high ability subjects than low ability subjects. Our results indicate that low ability subjects benefit more from the imposition of a goal assignment following declarative part-task training than high ability subjects. This effect is expected given the joint effects of individual differences in resource availability and changes in the performance resource function across stages of skill acquisition. From a pragmatic standpoint, the form of the ability - motivation interactions obtained in this research suggests that goal setting interventions may be potentially more, rather than less, useful among low aptitude individuals (compared with high aptitude individuals) when implemented after the initial phase of skill acquisition.

Ability Considerations

Individual differences in cognitive abilities clearly exerted an effect on performance in all conditions. The influence of ability on performance in the No Goal conditions reflects individual differences in resource availability and indicates the fundamental importance of this construct in complex skill acquisition. It is important to note, however, that the imposition of a goal assignment sometimes influences ability/performance correlations. In Experiment 1 (Early Goal) and Experiment 3 (Procedural Knowledge training condition), general ability/performance correlations declined when a goal was introduced. In Experiment 2 (Late Goal) and Experiment 3 (Declarative Knowledge training condition), the imposition of a goal was not associated with changes in general ability/performance correlations. These findings suggest that motivational interventions early in training may reduce the predictive validity of ability predictors of performance. However, these results suggest methods for optimal tailored training programs for trainees of different ability levels. Furthermore, such findings may be used as a springboard to search for further intervening conative or affective constructs that may directly *moderate* ability/performance correlations.

Motivational Considerations

An important issue raised by this research concerns the effectiveness of goal assignments on stimulating self-regulatory activities. Our results indicate that the allocation of resources to self-regulation appears to depend on subjects' perceived confidence in capability for goal attainment. In Experiment 1, low self-confidence ratings were associated with low levels of self-regulatory activity. In Experiment 3, task-specific confidence in capability, induced through positive prior experiences on the part-task rather than through reduction in attentional task demands, was associated with higher levels of self-regulatory activity. Our findings support Bandura's (1977; 1986) assertion that perceived confidence in capability for goal attainment is closely related to the initiation of self-regulatory processing.

Although perceptions of performance capability may stimulate self-regulatory activity, our data also suggest that individual differences in intellectual ability affect the character of self-regulatory activity. For example, low-ability subjects reported more spontaneous goal setting than high ability subjects in all experiments. Research in metacognition (see, for example, Brown, 1987, Campione, 1987, Kluwe, 1987) suggests that self-regulation processes may be viewed as comprised of two components; (1) cognitions about one's abilities, effort, and functioning, and (2) strategies for control over one's cognitive activity. From this perspective, individual differences in intellectual ability may exert an important influence on the efficiency with which persons who perceive themselves as capable of goal attainment engage self-regulatory activities. A metacognitive approach to our results would suggest that the influence of self-regulation on allocation policies depends upon both knowledge about one's

cognitive state as well as knowledge of, and use of, self-regulatory strategies to enhance performance. In the context of well-practiced activities, self-regulation strategies are often known and/or acquired with training. For example, seasoned computer programmers often develop specific strategies for writing elegant program code (e.g., taking a long-term, modular perspective), as opposed to use of "brute-force" methods of programming. Perceived capabilities for writing such code may determine whether these self-regulatory strategies are put to use, and the extent to which they are adhered to. In learning contexts, however, deficits in performance may arise from either self-evaluation of incapability to attain the goal and/or ineffective self-regulatory strategies. Thus, acquisition of expert programming skills may be influenced by perceptions of lack of intellectual ability and/or deficits in the self-regulatory strategies used to generate program code. Although perceptions of intellectual incapability may accurately reflect knowledge about one's deficits in self-regulatory strategies for controlling cognitive activity, these conditions can impair further efforts and preclude opportunities for the development of successful strategies. Environmental interventions that enhance perceptions of capabilities may immunize persons from premature reductions of effort toward cognitive strategy development (Bandura, in press). Our findings suggest further research in three areas: (1) the relationship between general intellectual ability and self-regulatory strategies controlling cognitive activity, (2) the influence of self-evaluation of capabilities on self-regulatory skill development, and (3) the cues used by persons in developing perceptions of cognitive capabilities and initiating self-regulatory activities.

The present experiments focused on only a small portion of the proposed model. Specifically, we examined the effects of proximal motivational processes on complex skill acquisition. Numerous studies have indicated the importance of distal motivational processes on task performance (see Feather, 1982; Lee, Locke, & Latham, in press). The present findings extend this work to the skill acquisition domain and suggest that distal motivational processes, such as goal commitment (e.g., Hollenbeck & Klein, 1987) and goals for task engagement (e.g., Dweck, 1986; Dweck & Leggett, in press) may influence proximal allocation policies as well as mobilization of attentional resources. Similarly, the present findings highlight how little is known about the characteristics of efficient self-regulatory strategies. Kuhl (1985) suggests a number of self-regulatory strategies that may be used to benefit performance. The influence of different motivational manipulations on the use of emotional control, motivation control, and other self-regulatory strategies represents another area of clear importance.

Finally, the present findings address conclusions drawn from recent meta-analytic studies of goal setting research (Tubbs, 1986; Mento, Steel, & Karren, 1987; Wood, Mento, & Locke, 1987). In particular, Wood et al. (1987) conclude that task complexity moderates the goal - performance relation such that the effect of goal setting on performance is stronger on simple tasks than complex tasks. Results obtained in this paper are consistent with Wood et. al's findings (see also Steele, 1988) and suggest a theoretically-based account of the individual differences, task demands, and motivational processes underlying these observed effects. In the proposed framework, complex, novel tasks impose greater attentional demands and reduce the opportunity for benefits of self-regulatory activity. In simple tasks, resource demands are likely to be less due to prior development of a declarative representation of the task. Goal setting in this context facilitates performance. The proposed framework and data presented in this paper suggest, however, that goal setting may facilitate complex task performance when presented in later phases of skill acquisition. Furthermore, the beneficial effects of goal setting at this phase are most likely to accrue to low, rather than high, ability persons. Further investigation of task complexity in terms of information processing demands and individual differences in resource availability appear warranted to clarify

the reason for the moderating effects obtained by Wood et al (1987).

Summary

In summary, the findings provide initial support for the integrated model emphasizing ability constraints on attentional resource capacity, dynamic cognitive resource demands imposed by tasks, the effects of resource availability on self-regulatory processing, and the influence of motivational processing on attentional task effort. Our findings indicate that interventions designed to engage motivational processing may impede task learning when presented prior to an understanding of what the task is about. In this instance, cognitive resources necessary for task understanding are diverted toward self-regulatory activities. Since persons have little or no spare resources at this phase of skill acquisition, these self-regulatory activities can provide little benefit for learning. In contrast, interventions designed to engage motivational processing following understanding of what the task involves (a declarative representation of the task), facilitate performance. Previous studies indicate a positive effect for goal setting on task performance among tasks that are neither completely novel or totally familiar. The results obtained in Experiment 3 (Declarative Knowledge training) complement these studies and further indicate that the beneficial effect is more pronounced for low ability persons than high ability persons. Further research, investigating the independent and interactive effects of intellectual abilities and motivational interventions on knowledge and action components of the self-regulatory system during knowledge compilation and procedural stages of skill acquisition is needed to further test the viability of the integrated/interactive model.

Implications. The three experiments described above involve an empirical demonstration/evaluation of the integrated perspective. By continuing to investigate the specific interactions between individual differences in cognitive and volitional determinants of learning, it will ultimately become feasible to develop more precise measures of learning abilities. Specifically, in addition to measures of several critical information processing parameters (such as those under development by the LAMP staff), it will become possible to boost predictions of individual differences in learning by using measures that assess the integral volitional processes underlying learning. The current research program is an essential first step toward this integration of information processing, cognitive ability, and volitional aspects of the learning process.

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X. TABLES

Table 1. ANOVAs: Experiment 1 -- No Goal/Early Goal (Goal Setting, Attention to Task Facets, Self-Reactions).

Factor	Spontaneous Goal Setting		On-Task Attention		Off-Task Attention		Attention to Performance Eval.	
	MS	F	MS	F	MS	F	MS	F
Ability	32.70	4.17*	93.09	1.26	.06	.02	194.01	7.39**
Goal	.00	.00	161.97	2.18	8.78	2.39	4.80	.18
Ability X Goal	6.29	.80	32.34	.44	.19	.05	1.41	.05
Error	7.85		74.16		3.67		26.24	
Factor	Positive Self-Reactions		Negative Self-Reactions		Task Difficulty		Task Pressure	
	MS	F	MS	F	MS	F	MS	F
Ability	91.93	2.57	111.04	10.64***	39.10	4.89*	8.94	1.75
Goal	2.32	.07	18.91	1.81	12.27	1.54	25.57	5.00*
Ability X Goal	61.68	1.73	18.16	1.74	9.27	1.16	5.02	.98
Error	35.76		10.44		8.00		5.11	
Performance Checking								
Factor	MS	F						
Ability	16.89	2.98						
Goal	83.14	14.69***						
Ability X Goal	18.43	3.26						
Error	5.66							

Degrees of Freedom (1,308) for each measure

* $p < .05$

** $p < .01$

*** $p < .001$

Table 2. ANOVAs: Experiment 2 -- No Goal/Late Goal (Goal Setting, Attention to Task Facets, Self-Reactions).

	Spontaneous Goal Setting		On-Task Attention		Off-Task Attention		Attention to Performance Eval.	
Factor	MS	F	MS	F	MS	F	MS	F
Ability	39.87	5.05*	28.88	.37	5.70	1.21	10.51	.39
Goal	54.89	6.96**	35.63	.46	.10	.02	14.15	.53
Ability X Goal	3.40	.43	106.35	1.36	5.83	1.23	107.01	3.98*
Error	7.89		77.98		4.73		26.89	
	Positive Self-Reactions		Negative Self-Reactions		Task Difficulty		Task Pressure	
Factor	MS	F	MS	F	MS	F	MS	F
Ability	130.30	3.21	23.78	2.17	21.34	2.50	14.35	2.80
Goal	12.89	.32	28.04	2.55	25.30	2.97	3.36	.66
Ability X Goal	34.38	.85	3.27	.30	23.09	2.71	1.88	.37
Error	40.60		10.98		8.53		5.12	
	Performance Checking							
Factor	MS	F						
Ability	.03	.00						
Goal	121.82	22.48***						
Ability X Goal	.10	.02						
Error	5.42							

Degrees of Freedom (1,301) for each measure

* $p < .05$

** $p < .01$

Table 3. Repeated-Measure ANOVA on Landings (Experiment 3).

Factors	df	MS	F
Between-Subjects Factors			
Ability	1	23959.94	74.82***
Training	1	1222.18	3.82
Goal	1	487.31	1.52
Ability X Training	1	169.18	.53
Ability X Goal	1	305.53	.95
Training X Goal	1	3813.35	11.91***
Ability X Training X Goal	1	412.92	1.29
Error	540	320.24	
Within-Subjects Factors			
Trials	5	40745.94	2047.61***
Ability X Trials	5	160.05	8.04***
Training X Trials	5	67.97	3.42**
Goal X Trials	5	36.32	1.83
Ability X Training X Trials	5	.59	.03
Ability X Goal X Trials	5	29.66	1.49
Training X Goal X Trials	5	27.52	1.38
Ability X Training X Goal X Trials	5	65.70	3.30**
Error	2700	19.90	

* $p < .05$

** $p < .01$

*** $p < .001$

Table 4. Repeated-Measure ANOVA on Errors (Experiment 3).

Factors	df	MS	F
Between-Subjects Factors			
Ability	1	4091.89	13.54***
Training	1	1262.28	4.18*
Goal	1	2015.62	6.67*
Ability X Training	1	297.30	.98
Ability X Goal	1	712.63	2.36
Training X Goal	1	730.54	2.42
Ability X Training X Goal	1	445.96	1.48
Error	540	302.14	
Within-Subjects Factors			
Trials	5	574.46	18.33***
Ability X Trials	5	200.28	6.39***
Training X Trials	5	259.28	8.27***
Goal X Trials	5	65.99	2.11
Ability X Training X Trials	5	11.12	.35
Ability X Goal X Trials	5	54.30	1.73
Training X Goal X Trials	5	12.96	.41
Ability X Training X Goal X Trials	5	42.65	1.36
Error	2700	31.35	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 5. ANOVAs: Experiment 3 -- Goal Setting, Attention to Task Facets, Self-Reactions.

Factor	Spontaneous Goal Setting		On-Task Attention		Off-Task Attention		Attention to Performance Eval.	
	MS	F	MS	F	MS	F	MS	F
Ability	36.78	4.33*	264.59	3.57	.70	.28	106.52	4.26*
Training	1.28	.15	.36	.00	3.04	1.21	11.59	.46
Goal	3.62	.43	87.95	1.19	3.71	1.47	40.17	1.61
Ability X Training	2.53	.30	65.27	.88	.40	.16	32.27	1.29
Ability X Goal	42.21	4.97*	1.26	.02	4.29	1.71	27.56	1.10
Training X Goal	54.81	6.45*	326.04	4.40*	26.80	10.65***	168.29	6.73**
Ability X Training X Goal	.96	.11	243.43	3.29	11.18	4.44*	.00	.00
Error	8.50		74.04		2.52		25.00	
Performance Checking								
Factor	Positive Self-Reactions		Negative Self-Reactions		Task Difficulty		Task Pressure	
	MS	F	MS	F	MS	F	MS	F
Ability	420.84	10.30***	73.60	5.44*	16.95	2.63	38.42	8.35**
Training	8.45	.21	35.40	2.61	.11	.02	11.24	2.44
Goal	.16	.00	537.19	39.68***	160.03	24.84***	52.01	11.31***
Ability X Training	4.87	.12	.24	.02	.55	.09	1.84	.40
Ability X Goal	24.28	.59	19.89	1.47	1.11	.17	.16	.04
Training X Goal	30.62	.75	120.57	8.91**	10.61	1.65	5.35	1.16
Ability X Training X Goal	143.51	3.51	2.98	.22	.01	.00	10.34	2.25
Error	40.86		14.79		6.44		4.60	

Degrees of Freedom (1,539) for each measure

* $p < .05$
** $p < .01$
*** $p < .001$

XI. FIGURES

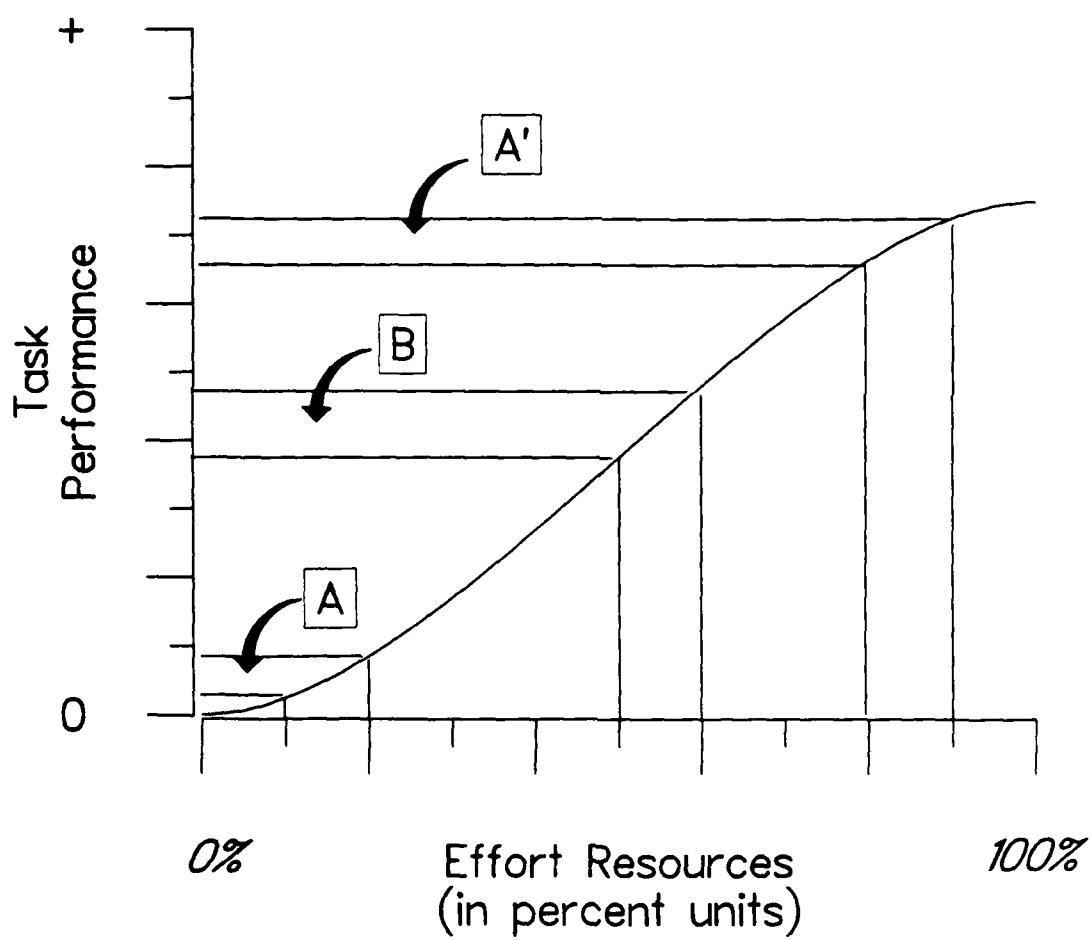


Figure 1.

An example performance-resource function. The function is mostly resource-dependent, but is more so in segment "B" and less so in segments "A" and "A'".

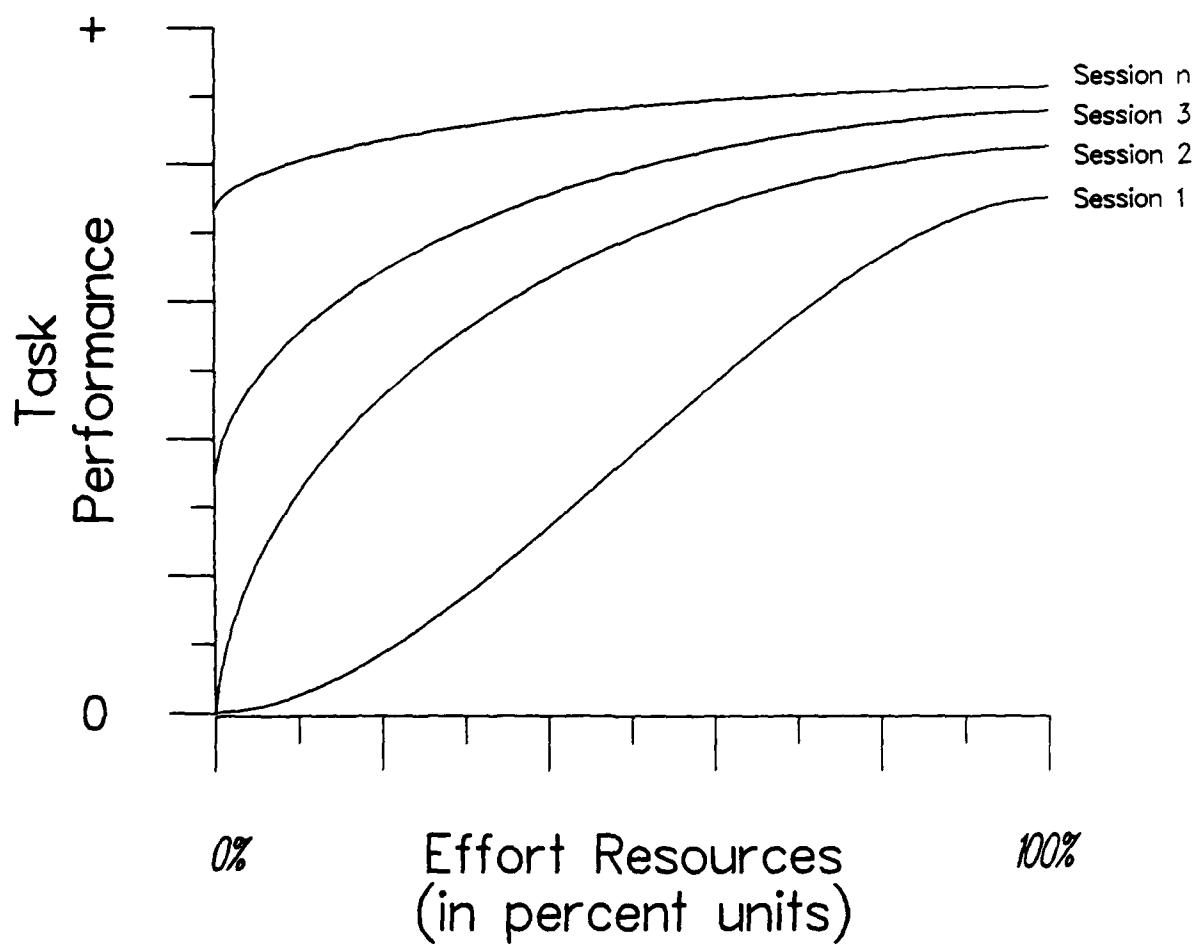


Figure 2. Changes in performance-resource functions as a result of practice. While the performance-resource function is initially resource-dependent (Session 1), as the number of practice sessions increases, the task becomes more resource-insensitive (as the skill becomes proceduralized).

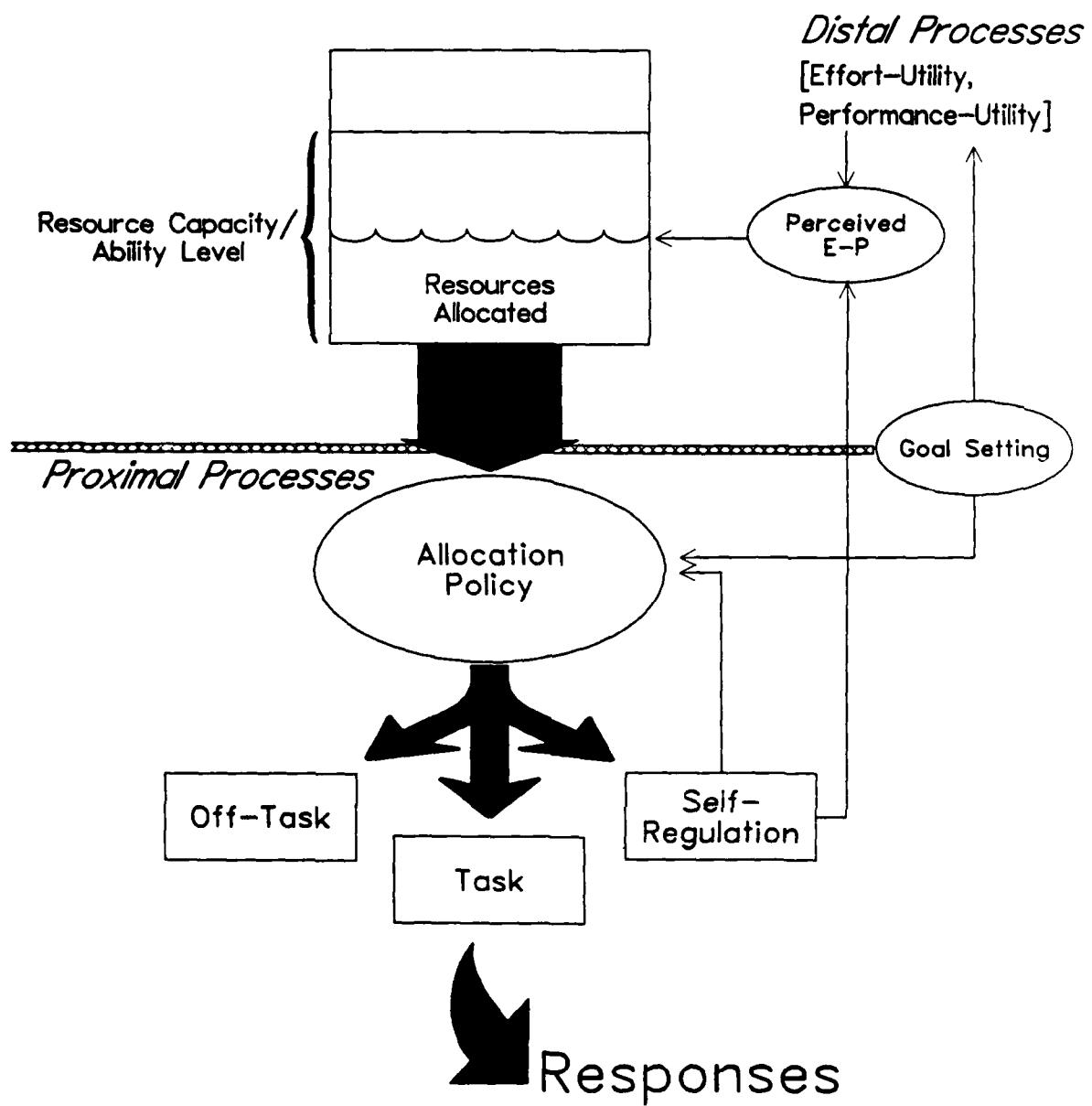


Figure 3.

A model of ability/motivation interactions for attentional effort. The model is derived from a model of attention proposed by Kahneman (1973). See text for description of model components.

FLT#	TYPE	FUEL	POS.	Score : 150
			3 n	Landing Pts: 150 Penalty Pts: 0
			3 s	Runways : DRY
161	747	5	3 e	Wind : 40 - 50 knots from SOUTH
			3 w	
403	747	6	2 n	Flts in Queue: ...
889	727	6	2 s	<F1> to accept
			2 e	
			2 w	
631	727	6	1 n	Winds 40-50 knots
144	prop	5	1 s	Winds from South
903	DC10	6	1 e	Runways dry
-> 122	747	*	1 w	
n	—————		s	#1
n	————727————		s	#2
w			e	#3
w			e	#4

Figure 4.

The Kanfer/Ackerman Air Traffic Controller Task. The figure is a literal static representation of the real-time task display. See text for a description of task elements.

RULE	KEYWORD
RULE 1: PLANES MUST LAND INTO THE WIND. (That is, if the wind is from the South, the plane must be landed on a n-s runway)	[DIRECTION]
RULE 2: PLANES CAN ONLY LAND FROM LEVEL 1.	[LEVEL]
RULE 3: PLANES IN THE HOLD PATTERN CAN ONLY MOVE 1 LEVEL AT A TIME, BUT TO ANY AVAILABLE POSITION IN THAT LEVEL.	[HOLD]
RULE 4: GROUND CONDITIONS AND WIND SPEED DETERMINE THE RUNWAY LENGTH REQUIRED BY DIFFERENT PLANE TYPES.	[LENGTH]
[ALL PLANES CAN USE LONG RUNWAYS.]	
IN PARTICULAR:	
747's ALWAYS REQUIRE LONG RUNWAYS.	
DC10's CAN USE SHORT RUNWAYS ONLY WHEN RUNWAYS ARE DRY OR WET AND WIND SPEED IS LESS THAN 40 KNOTS.	
727's CAN USE SHORT RUNWAYS ONLY WHEN THE RUNWAYS ARE DRY OR WIND SPEED IS 0 - 20 KNOTS.	
PROP's CAN ALWAYS USE SHORT RUNWAYS.	
RULE 5: PLANES WITH LESS THAN 3 MINUTES FUEL LEFT MUST BE LANDED IMMEDIATELY.	[FUEL]
RULE 6: ONLY ONE PLANE AT A TIME CAN OCCUPY A RUNWAY.	[OCCUPIED]

Figure 5.

A list of operational rules for the ATC task. Keywords (on the right side) are used to index rule pop-up keys during the task.

FLT#	TYPE	FUEL	POS.
400	747	5	3 n 3 s 3 e 3 w 2 n 2 s 2 e 2 w
430	prop	5	1 n
889	727	5	1 s
651	747	5	1 e
15	DC10	5	1 w

n _____ s #1 <-
 n _____ s #2
 w | | | | | | | DC10 | | | | | e #3
 w | | | | | | | 727 | e #4

Score : 1450
 Landing Pts: 1500 Penalty Pts: -50
 Runways : WET
 Wind : 0 - 20 knots from EAST

Flts in Queue:
 <F1> to accept

Error: Must use N-S runways
 when wind direction is N or
 S and E-W runways when E or W.

Figure 6. An illustration of error feedback in the ATC task. The error message is displayed in the lower right side of the figure.

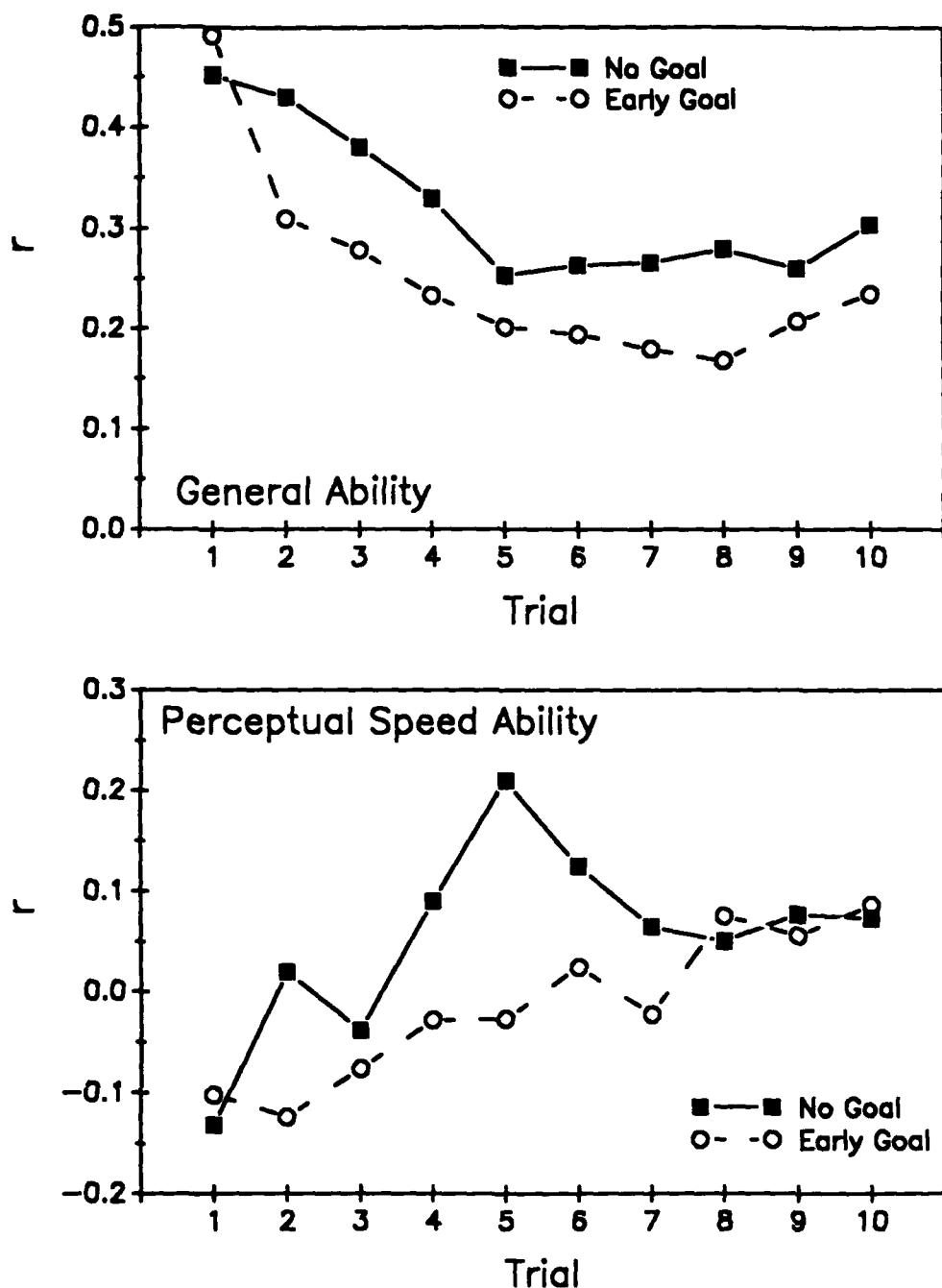


Figure 7. Ability/performance correlations by ability factor, condition, and ATC task trial. Upper Panel: General ability/performance correlations. Lower Panel: Perceptual speed/performance correlations.

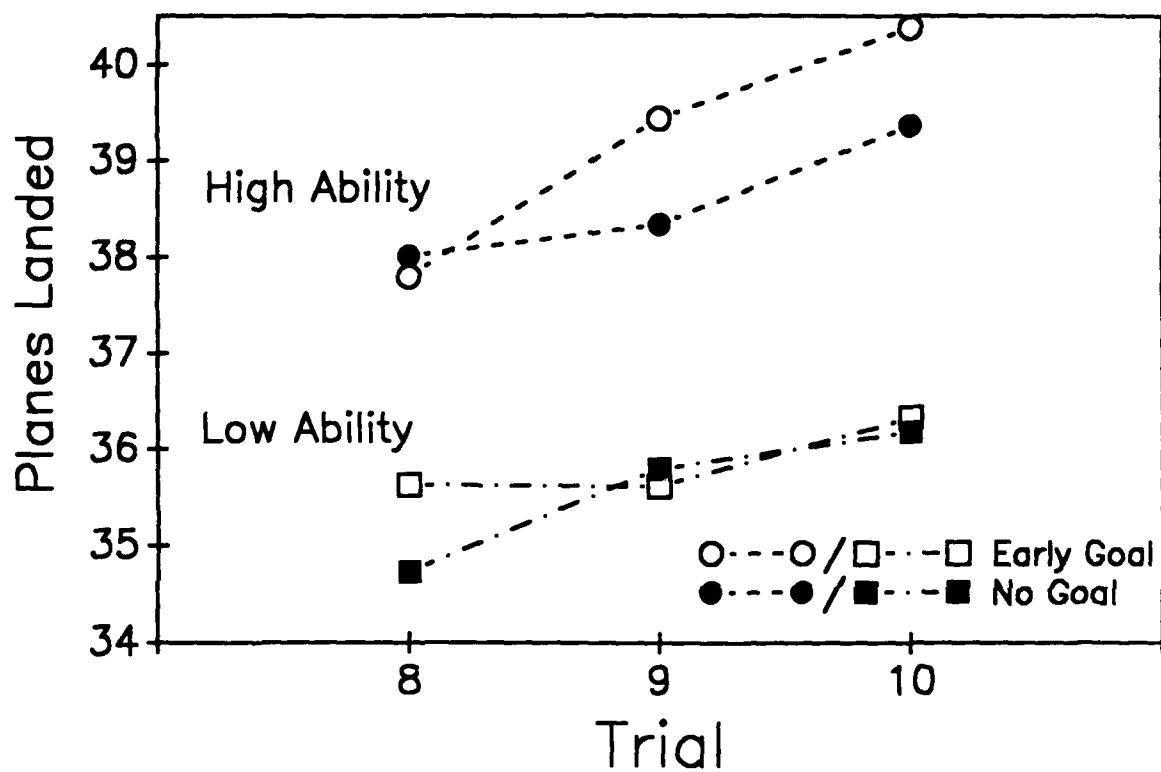


Figure 8. Planes landed as a function of ATC task trial - for final three trials, by condition, and by ability group (median split).

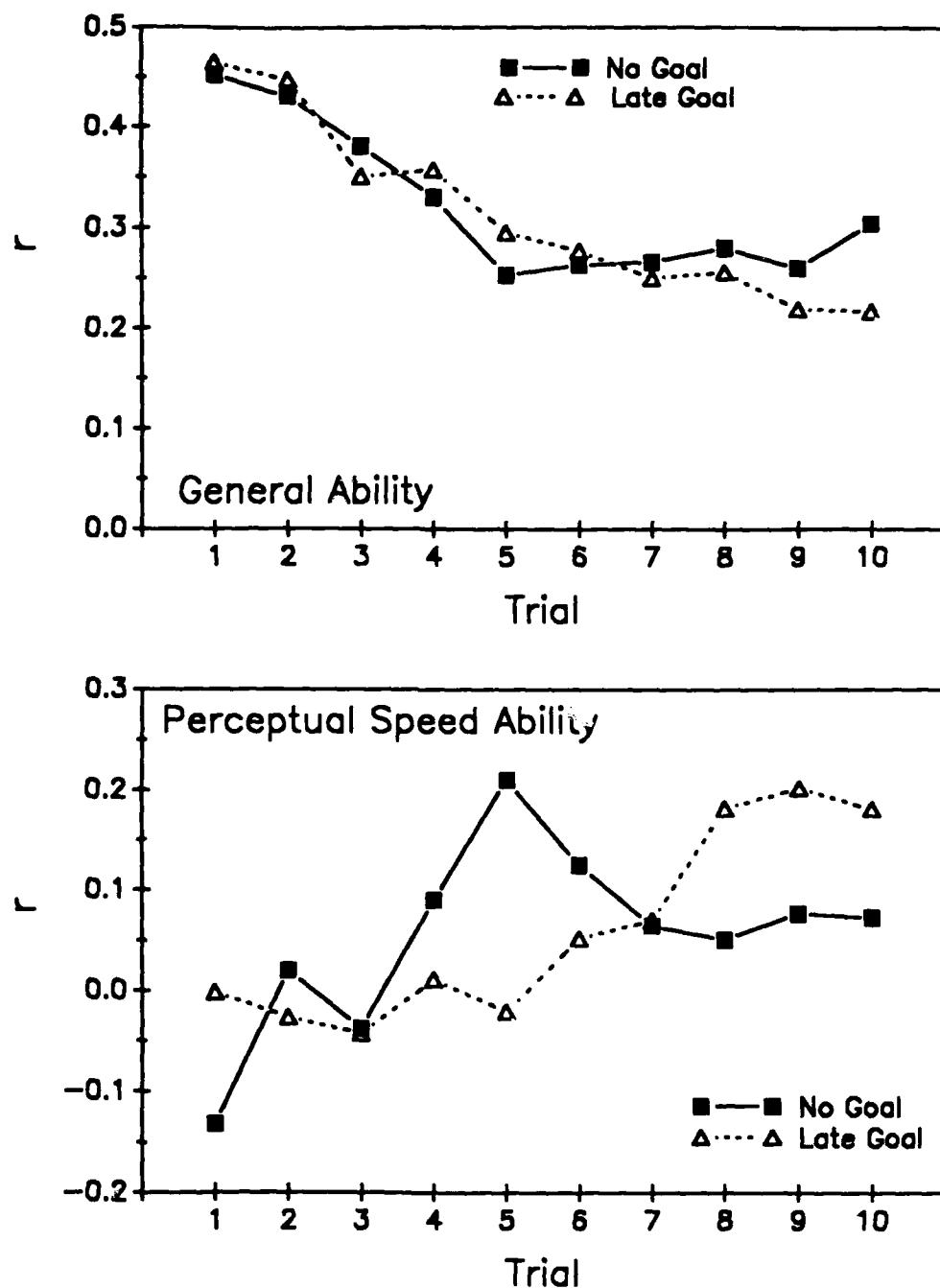


Figure 9.

Ability/performance correlations by ability factor, condition, and ATC task trial. Upper Panel: General ability/performance correlations. Lower Panel: Perceptual speed/performance correlations. No Goal (from Experiment 1).

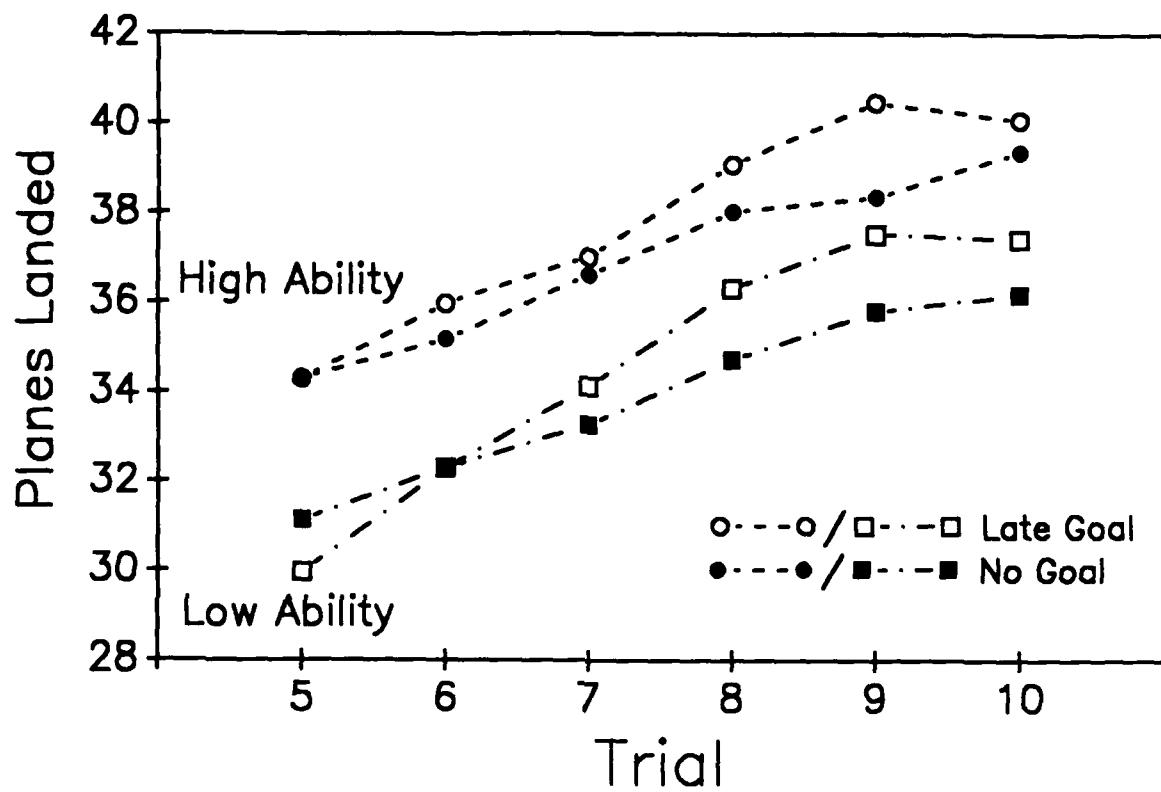


Figure 10. Planes landed as a function of ATC task trial - for final three trials, by condition, and by ability group (median split). No Goal (from Experiment 1).

FLT#	TYPE	FUEL	POS.
---	---	---	---
			3 n
			3 s
			3 e
			3 w
157	747	* 2	2 n
577	727	* 2	2 s
19	DC10	* 2	2 e
			2 w
			1 n
469	747	5	1 s
502	DC10	5	1 e
			1 w
n	-----	s	#1 <-
n	-----	s	#2
w		e	#3
w		e	#4

Score : 0
 Landing Pts: 0 Penalty Pts: 0
 Runways : DRY
 Wind : 0 - 20 knots from SOUTH

Flts in Queue: ...
 <F1> to accept

Is ← a legal move?

Can use short runways when:
 747 - Never Prop - Always
 DC10 - Not Icy & not 40-50 knots
 727 - Dry or 0-20 knots

Figure 11.

An illustration of a Declarative knowledge part-task training trial. The box in the lower right side of the figure shows Rule 4, the box above the rule shows the question asked of the subject.

FLT#	TYPE	FUEL	POS.	Score : 0 Landing Pts: 0 Penalty Pts: 0 Runways : WET Wind : 40 - 50 knots from SOUTH
		---	3 n 3 s 3 e 3 w 2 n 2 s 2 e 2 w	Flts in Queue: <F1> to accept
496	prop	5	1 n 1 s 1 e	Type the following keys: ↑ ← ↓ ↓ ↓ ↓ ←
286	DC10	5	1 w	
n	-----	s	#1	
n	-----	s	#2	
w		e	#3	
w		e	#4	

Figure 12. An illustration of a Procedural knowledge part-task training trial. The box in the middle right side of the figure shows the instructions to the subject.

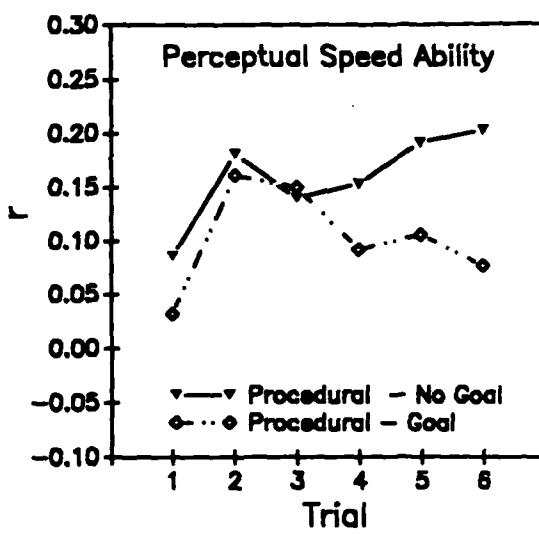
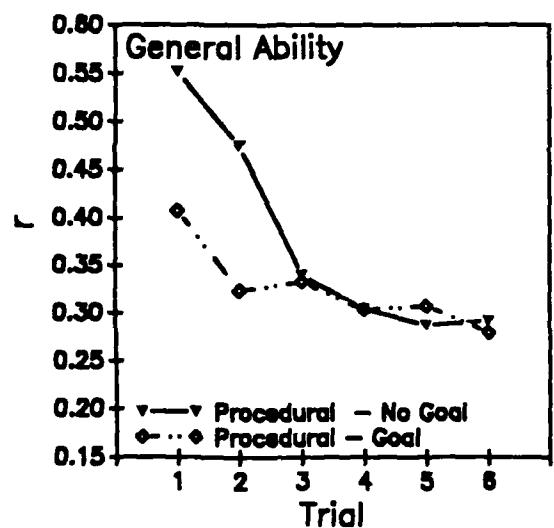
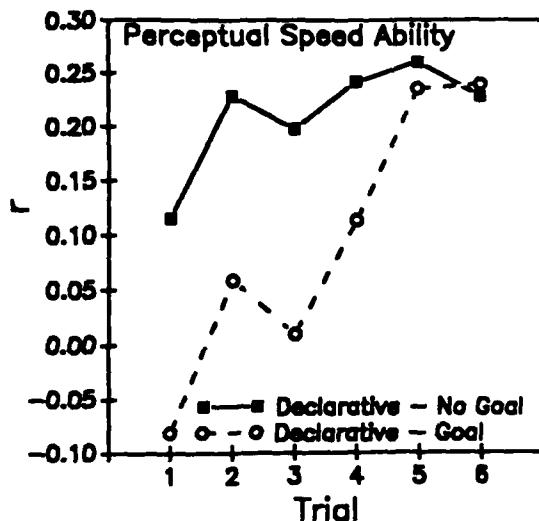
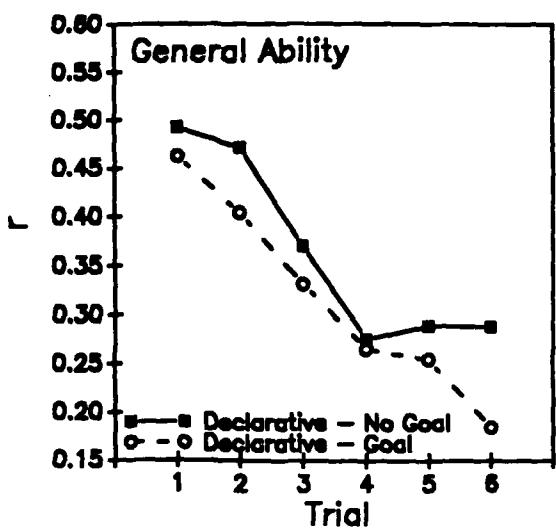


Figure 13. Ability/performance correlations by ability factor, condition, and full-task practice trial. Upper Left Panel: Declarative - General Ability; Upper Right Panel: Declarative - Perceptual Speed Ability; Lower Left Panel: Procedural - General Ability; Lower Right Panel: Procedural - Perceptual Speed Ability.

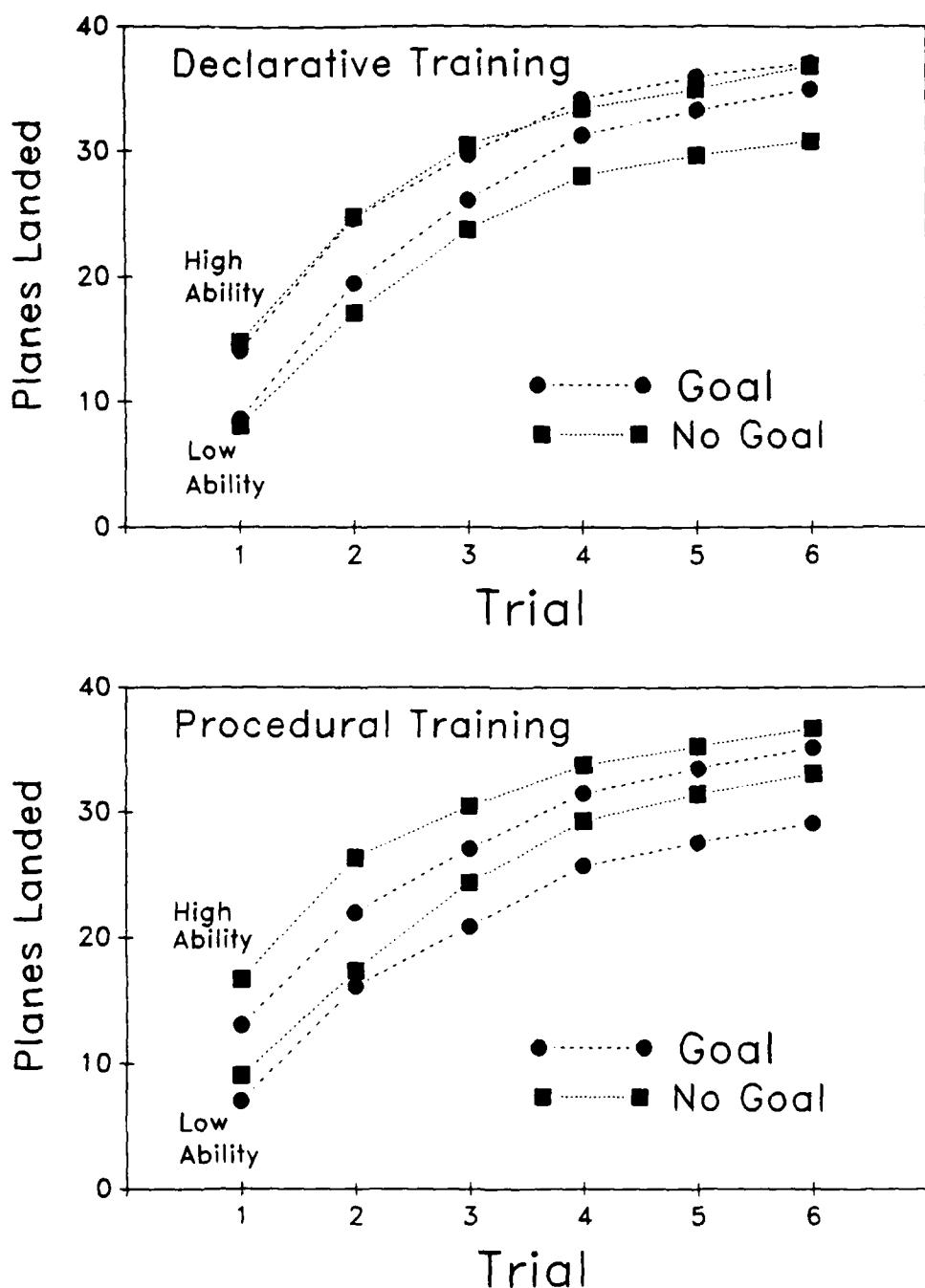


Figure 14. Planes landed as a function of full ATC task trial, by condition, and by ability group (median split). Upper Panel: Declarative part-task training conditions; Lower Panel: Procedural part-task training conditions.

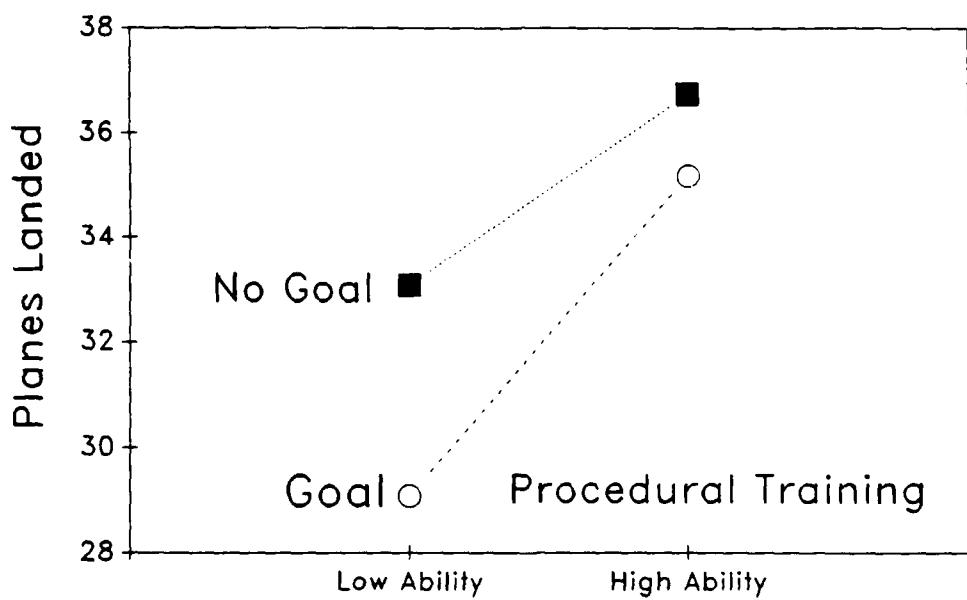
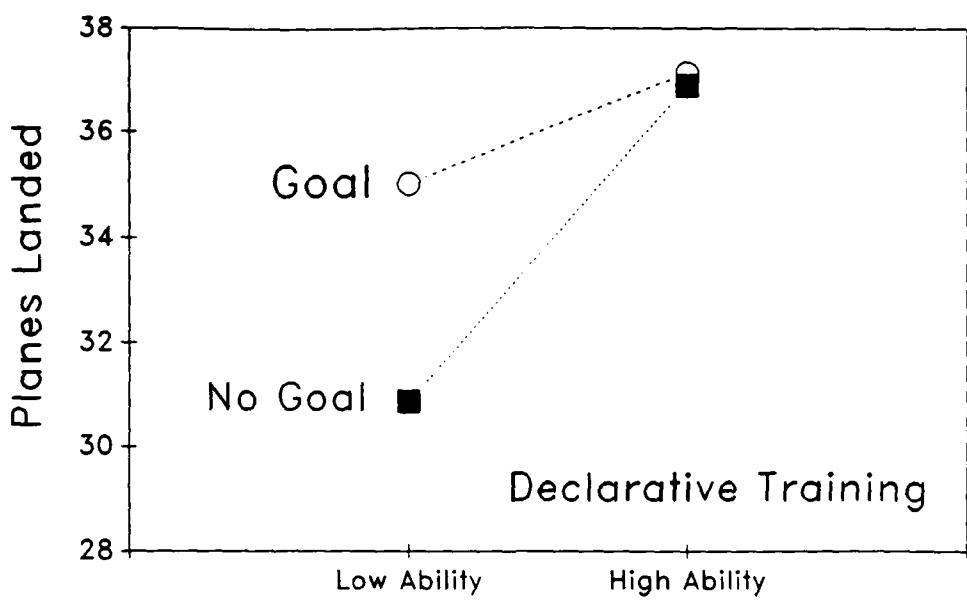


Figure 15. Planes landed -- Trial 6, by condition and by ability group (median split). Upper Panel: Declarative part-task training conditions; Lower Panel: Procedural part-task training conditions.